WATER RESOURCES OF THE WIND RIVER INDIAN RESERVATION, WYOMING

By Richard L. Daddow

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CONTENTS

	Pa
Abstract	•••••
Introduction	
Purpose and scope	
Methods of investigation	
Previous studies	
Numbering system for wells and springs	
Numbering system for surface-water sites	
Acknowledgments	
Description of the study area	
•	
Geographic setting	
Climate	
Geologic setting	
Water use	
Ground-water resources	
Quaternary deposits	
Flood-plain alluvium	
Slope wash and alluvium	
Terrace deposits	••••••
Glacial deposits	
Altitude and configuration of the water table for two selected areas	
Tertiary rocks	
Volcaniclastic rocks	
Wind River Formation	
Mesozoic rocks	
Cody Shale	
Frontier Formation	
Cloverly Formation	
Nugget Sandstone	
Chugwater Group	
Paleozoic rocks	
Phosphoria Formation and related rocks	
Tensleep Sandstone	
Madison Limestone	
Precambrian rocks	
Surface-water resources	
Streams	
Streams with streamflow-gaging stations	
Miscellaneous surface-water sites	***************************************
Flow characteristics of streams with streamflow-gaging stations	
Flow characteristics of streams without streamflow-gaging stations	***************************************
Lakes and reservoirs	*******
Water quality	
Water quality in relation to water use	
Public-supply and domestic use	
Agricultural use	
Ground-water quality	
Quaternary deposits	
Wind River flood-plain alluvium	
•	
Little Wind River flood-plain alluvium	

CONTENTS--Continued

	Page
Popo Agie River flood-plain alluvium	50
Owl Creek flood-plain alluvium	
Slope wash and alluvium	
Terrace deposits	
Glacial deposits	
Tertiary rocks	52
Volcaniclastic rocks	
Wind River Formation	
Mesozoic rocks	53
Cody Shale	53
Frontier Formation	53
Cloverly Formation	53
Nugget Sandstone	54
Chugwater Group	54
Paleozoic rocks	
Phosphoria Formation and related rocks	
Tensleep Sandstone	55
Madison Limestone	55
Nitrates	56
Trace elements	56
Radiochemicals	58
Pesticides	58
Surface-water quality	58
Major chemical characteristics of streams	62
Chemical quality in relation to streamflow	63
Chemical quality in relation to geographic location and geology	68
Nitrates	71
Trace elements	71
Radiochemicals	72
Pesticides	73
Summary	73
References	76
Glossary	79
Appendix 1Statistical summaries of streamflow data for selected streamflow-gaging stations on or	
near the Wind River Indian Reservation, Wyoming	83
Appendix 2Statistical summaries of water-quality data for selected streamflow-gaging stations on or	
near the Wind River Indian Reservation, Wyoming, with 4 years or more of major-	
constituents analyses through 1990	109

PLATE [Plates are in pocket]

- Plate 1. Map showing location of selected wells, springs, and the Wind River Federal Irrigation Project area, Wind River Indian Reservation, Wyoming, 1991
- Plate 2. Map showing water-table contours and depth to water, April-May 1991, in Quaternary deposits in the Upper Little Wind River and Mill Creek drainage basins and the lower Little Wind River drainage basin, Wind River Indian Reservation, Wyoming
- Plate 3. Map showing water-table contours and depth to water, May 1991, in the terrace deposits and the Meadow Creek flood-plain alluvium, Crowheart area, Wind River Indian Reservation, Wyoming
- Plate 4. Map showing location of selected streamflow-gaging stations and miscellaneous surface-water sites on or near the Wind River Indian Reservation, Wyoming, through 1990

FIGURES

		Pa
1.	Map showing location of the study area and selected weather stations on or near the Wind River Indian Reservation, Wyoming	
2.	Diagram showing numbering system for wells and springs in the Wind River Indian Reservation, Wyoming	
3.	Map showing location of the Wind River and Owl Creek drainage basins, Wyoming	
	Map showing generalized geology of the Wind River Indian Reservation, Wyoming	1
5.	Graphs showing mean monthly discharges at representative streamflow-gaging stations on a perennial stream and an intermittent stream, Wind River Indian Reservation, Wyoming	3
6.	Flow-duration curves for representative streamflow-gaging stations on an unregulated stream and a regulated stream, Wind River Indian Reservation, Wyoming	3
	Graphs showing relation of dissolved-solids concentration to specific conductance for water samples collected at two selected streamflow-gaging stations, Wind River Indian Reservation, Wyoming	6
8.	Diagrams showing lower quartile, median, and upper quartile concentrations of dissolved solids in water samples collected at different flow ranges at two selected streamflow-gaging stations for period of record through 1990, Wind River Indian Reservation, Wyoming	ć
9.	Stiff diagrams of the mean concentration of chemical analyses of water samples for period of record through 1990 at five selected streamflow-gaging stations on the Wind River, Wyoming	6
TABL	ES	
1.	Mean-annual precipitation and mean-annual temperature for selected weather stations on or near the Wind River Indian Reservation, Wyoming	
2.	Major geologic units and percentage of reservation area included in each generalized geologic-map unit, Wind River Indian Reservation, Wyoming	1
3.	Source of water and water-use data for selected public water-supply systems, Wind River Indian Reservation, Wyoming	1
	Summary of selected ground-water data for wells completed in Quaternary deposits, Wind River Indian Reservation, Wyoming	1
5.	Summary of selected ground-water data for wells completed in and springs flowing from Tertiary, Mesozoic, and Paleozoic rocks on or near the Wind River Indian Reservation, Wyoming	2
6.	Type and period of record for discharge measurements, and availability of water-quality data for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990	2
7.	Type of record for discharge measurements and water-quality analyses for miscellaneous surface- water sites on or near the Wind River Indian Reservation, Wyoming, through 1990	3
8.	Flow characteristics for selected streams without or recent streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming	3
9.	Primary and secondary drinking-water regulations for public-water supplies	4
	State of Wyoming water-quality standards of ground water for agricultural and livestock use	2
	Summary of selected water-quality data for wells completed in flood-plain alluvium, Wind River Indian Reservation, Wyoming	4
12.	Summary of selected water-quality data for wells completed in and springs flowing from slope wash and alluvium, terrace deposits, glacial deposits, volcaniclastic rocks, and the Wind River Formation, Wind River Indian Reservation, Wyoming	4
13.	Summary of selected water-quality data for wells completed in and springs flowing from selected Mesozoic and Paleozoic rocks, Wind River Indian Reservation, Wyoming	4
14.	Linear-regression analyses of dissolved-solids concentration in relation to specific conductance for water samples from wells completed in and springs flowing from selected geologic units, Wind River Indian Reservation, Wyoming	4

TABLES--Continued

		Page
15.	Number of water-quality samples in hardness, salinity-hazard, and sodium-hazard classes for selected geologic units, Wind River Indian Reservation, Wyoming, through 1990	49
16.	Ground-water quality samples collected from wells with nitrate concentrations of 5 milligrams per liter or more, Wind River Indian Reservation, Wyoming	57
17.	Period of record and number of analyses for different types of water-quality data for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990	59
18.	Selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, with 4 years or more of major-constituent analyses through 1990	63
19.	Linear-regression analyses of dissolved-solids concentration in relation to specific conductance for water samples collected from selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming	64
20.	Number of water-quality samples in hardness, salinity-hazard, and sodium-hazard classes for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990	66

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	Ву	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square foot (ft ²)	0.09294	square meter
square mile (mi ²)	2.59	square kilometer
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per square mile (acre-ft/mi ²)	476.1	cubic meter per square kilomete
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second
gallon per day (gal/d)	3.785	liter per day
gallon per minute (gal/min)	0.06309	liter per second
gallon per minute per foot[(gal/min)/ft]	0.207	liter per second per meter
gallon per day per squared foot [(gal/d)/ft ²]	0.6791	liter per day per square meter
pound per square inch (lb/in ²)	6.895	kilopascal

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) as follows:

$$^{\circ}F = 9/5 (^{\circ}C) + 32$$

$$^{\circ}C = 5/9 (^{\circ}F - 32)$$

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS--Continued

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Water year: In this report, "water year" refers to the 12-month period from October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the water year ending on September 30, 1989, is called "water year 1989." Streamflow records of the U.S. Geological Survey are compiled and reported for water years.

Year: In this report, "year" refers to the calendar year (January 1 through December 31).

Abbreviated water-quality units used in this report:

mg/L milligram per liter
pCi/L picocurie per liter

µg/L microgram per liter

μS/cm microsiemens per centimeter at 25 degrees Celsius

mrem/yr milliroentgen equivalent man per year

Other abbreviations and symbols:

MCL maximum contaminant level

SMCL secondary maximum contaminant level

± plus or minus

 α alpha

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ABSTRACT

Comprehensive information about the water resources on the Wind River Indian Reservation, west-central Wyoming is needed to manage the existing water uses and develop future water supplies for Shoshone and Northern Arapahoe Tribal members and others who live on or near the reservation. As a result, the U.S. Geological Survey, in cooperation with the Shoshone Triba and the Northern Arapahoe Tribe, conducted a comprehensive study of the water resources of the reservation.

Rocks from all geologic periods except those of Silurian age are present on the reservation. Ground water, as well as springs, are present in many of these geologic units. These units provide water for public-supply, domestic, agricultural, and industrial uses, and are a potential source of water for irrigation on the reservation. At least 507 wells are completed in deposits of Quaternary age on the reservation, and most of these wells are less than 50 feet deep. Median yields from wells completed in different deposits of Quaternary age ranged from 6 to 20 gallons per minute.

The Wind River Formation of Tertiary age is the major source of drinking water for domestic and public-supply uses. Most of the 608 wells in this formation are completed in permeable, lenticular, and discontinuous sandstone deposits. Inventoried well depths ranged from 37 to 994 feet, with a median depth of 190 feet. Yields ranged from about 0.1 to 350 gallons per minute, with a median yield of 20 gallons per minute.

One hundred and thirteen wells are completed in five Mesozoic and three Paleozoic age geologic units. Wells completed in the Mesozoic units are usually less than 150 feet deep. Median yields ranged from 5 gallons per minute for the Cody Shale of Cretaceous age to 55 gallons per minute for the Nugget Sandstone of Jurassic (?) and Triassic (?) age. The Paleozoic units consist of the Tensleep Sandstone of Pennsylvanian age and the Madison Limestone of Mississippian age and these two units are potentially the most productive water-yielding geologic units on the reservation, with estimated yields of as much as 1,000 gallons per minute.

Streams provide most of the water for irrigation, which is the largest water use on the reservation. Sixty active or inactive U.S. Geological Survey streamflow-gaging stations are located on perennial, intermittent, and ephemeral streams on or near the reservation. Statistical summaries of streamflow data for 24 gaging stations with 10 or more years of daily discharge records indicate that low-flow, high-flow, and flow-duration characteristics of streams on the reservation are extremely variable. Average annual runoff was 122 to 1,150 acre-feet per square mile on streams with gaging stations.

The chemical quality of ground water on the reservation is variable. In water sampled from the Little Wind River and Popo Agie River flood-plain alluvium near the mountains, dissolved-solids concentrations generally were less than 400 mg/L (milligrams per liter), and ionic compositions were dominated by calcium and bicarbonate. With increasing distance from the mountains, dissolved-solids concentrations ranged from about 600 to about 750 mg/L, and ionic composition consisted of a mixture of calcium, magnesium, and sodium cations with mostly sulfate anions. These changes in the chemical quality of water downgradient could be caused by lithologic changes in the flood-plain alluvium, a

downgradient increase in recharge from irrigation return flow, or the increased contact time of water with or seepage of water from the underlying Cody Shale and the Frontier Formation of Cretaceous age, both of which contain substantial amounts of soluble minerals. Water samples collected in the Wind River Formation had dissolved-solids concentrations ranging from 211 to 5,110 mg/L, and ionic composition varied from mixed calcium and sodium cations with mostly bicarbonate ions to a dominance of sodium and sulfate ions. Water samples collected in most of the Mesozoic geologic units had median dissolved-solids concentrations ranging from 800 to 2,540 mg/L, and variable ionic compositions. Dissolved-solids concentrations of less than 250 mg/L and ionic composition dominated by calcium and bicarbonate ions were typical chemical-quality characteristics of the water samples collected from five wells completed in the Tensleep Sandstone and the Madison Limestone.

Water-quality samples have been collected at 33 streamflow-gaging stations and 28 miscellaneous surface-water sites on or near the reservation. Statistical summaries of chemical-quality data from 12 gaging stations with 4 years or more of records indicate that chemical quality of the streams is related to changes in streamflow, geology, and downstream location. Water samples from most perennial streams in or near mountainous areas had dissolved-solids concentrations less than 200 mg/L and ionic composition dominated by calcium and bicarbonate ions. With increasing distance from the mountains, water samples from most perennial streams had dissolved-solids concentrations ranging from about 400 to about 600 mg/L and ionic composition of mostly calcium and sodium cations and sulfate anions. Water samples from intermittent streams had dissolved solids concentrations ranging from about 1,100 to about 3,500 mg/L and ionic composition of sodium and calcium cations with a dominance of sulfate anions.

INTRODUCTION

The water resources of the Wind River Indian Reservation, Wyoming (fig. 1), hereinafter referred to as the reservation, are important to the Shoshone and Northern Arapahoe tribal members and others who live on or near the reservation. Comprehensive information of the water resources is important for the successful management and protection of existing water uses and supplies. Detailed water-resources information also is needed for the planning and design of new water supplies, and other related economic development on the reservation. Uses of both ground and surface water on the reservation are extensive, diverse, and increasing due to increases in population, industrial and agricultural growth, and recreational activities. Water-resource management and allocation on the reservation have received a high priority because of a 1988 Supreme Court of Wyoming decision (In regards to: The general adjudication of all rights to use water in the Big Horn River system and all other sources, State of Wyoming; The State of Wyoming v. Shoshone and Arapahoe Tribes, et.al.; 753P.2D76, Wyoming 1988) granting a surface-water right of about 500,000 acre-ft (acre-feet) annually to the Shoshone Tribe and Northern Arapahoe Tribe. This Federal-reserved water right has the most senior waterrights appropriation date (1868) in the Wind River drainage basin. To obtain information that is needed to plan for and manage the increased demands for water on the reservation, the U.S. Geological Survey (USGS), in cooperation with the Shoshone Tribe and Northern Arapahoe Tribe, conducted a study to describe and evaluate the water resources. Additional hydrologic data were collected as part of the study where such data were lacking or considered inadequate or where water quality was a concern.

Purpose and Scope

The ground-water and surface-water resources and the chemical quality of these resources on the reservation are described in this report. Site characteristics, well yields, water levels, and chemical quality of the ground water for 14 major geologic units are described and evaluated on the basis of hydrologic data obtained from inventoried water-supply wells and springs. An inventory and data summary were compiled for 60 streamflow-gaging stations and 39 miscellaneous surface-water sites on or near the reservation. Flow characteristics are evaluated for streams with and without streamflow-gaging stations. A comprehensive

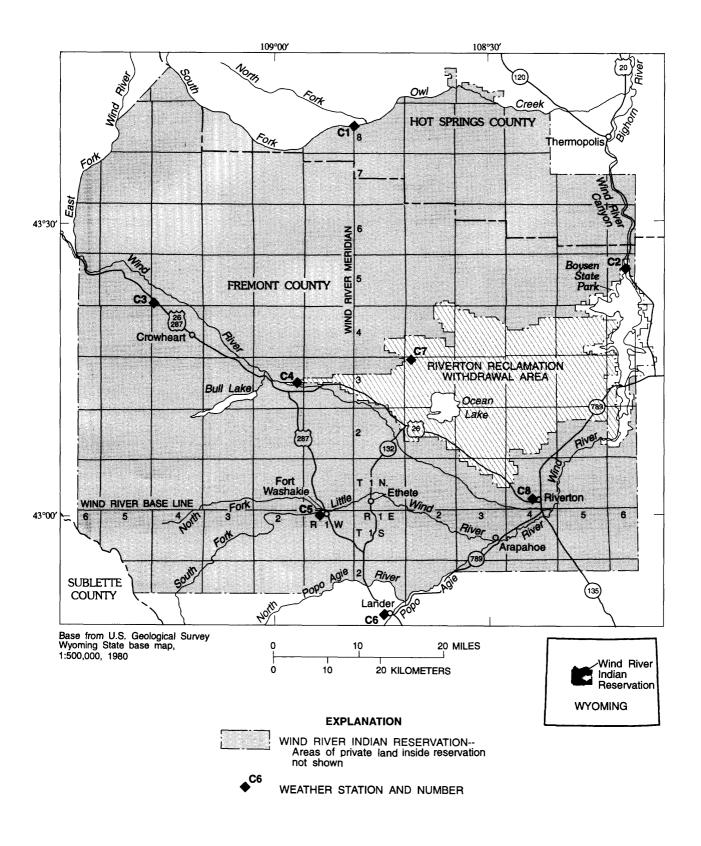


Figure 1. Location of the study area and selected weather stations on or near the Wind River Indian Reservation, Wyoming.

summary of the type, number, and period of record of water-quality analyses is included for 33 streamflow-gaging stations on or near the reservation. Chemical-quality data from 12 representative gaging stations with 4 or more years of chemical-quality data are statistically summarized and used to evaluate the general chemical-quality characteristics of streams on or near the reservation. In addition, a glossary is provided after the references to assist the reader with unfamiliar terms.

Methods of Investigation

Water-resources data for the reservation were obtained from numerous Federal and State agencies, and private consulting firms. A detailed literature search also provided data about the geology and hydrology of the reservation. Well records and water-quality data were obtained from the U.S. Public Health Service, Indian Health Services (IHS), and Bureau of Indian Affairs (BIA) offices in Fort Washakie, Wyoming. Computerized data from the USGS on water resources of the reservation also were compiled and updated.

Inventory records of the water-supply wells and springs on the reservation were comprehensively compiled, and these data were used to identify and evaluate the ground-water resources. Nearly 1,360 wells were inventoried (Daddow, 1992), including most of the water-supply wells drilled before 1990 that are on reservation trust lands or lands owned by tribal members, and most water-supply wells drilled before 1966 on private lands on the reservation. Nearly 260 springs were inventoried (Daddow, 1992), including springs identified on 7.5-minute topographic quadrangle maps. Springs not identified on quadrangle maps but listed in the soil and range resources inventory of the reservation (U.S. Department of the Interior, 1962) were included in the spring inventory. Ground-water and water-quality data for the inventoried wells and springs are listed in Daddow (1992). These inventoried wells and springs are shown on plate 1 of this report.

Onsite work for this study was conducted from August 1988 through May 1991. Discharge, flow rate, water level, temperature, pH, or specific conductance were measured at 274 wells, 23 springs, and 42 surfacewater (stream, canal, or drain) sites. Chemical-quality samples were collected at 45 wells, 21 springs, and 34 surface-water sites. Methods and guidelines used for the collection and onsite analysis of these water-quality samples are described in Wells and others (1990). Discharge from selected springs, streams, canals, and drains were measured using techniques described by Rantz and others (1982).

Water-quality data evaluated and summarized in this report came from different laboratories and time periods, and different analytical methods were used. Quality-control checks were performed on all chemical-quality data included in this report. The quality-control methods used are described in Friedman and Erdmann (1982, p. 103-108). The primary quality-control check, commonly called a "chemical-balance check," was based on the percentage difference between the sums of the milliequivalents of major cations and anions. Chemical analyses with chemical-balance check values greater than \pm 6-percent difference were not accepted and not used in this report. The only exception was for chemical analyses of water samples where the sum of the cations and anions was less than 2.5 milliequivalents. The chemical-balance check for these chemical analyses was based on the percentage-difference curve shown in Friedman and Erdmann (1982, p. 104, fig. 15).

Previous Studies

Numerous water-resources studies of the reservation have been completed. McGreevy and others (1969) provided detailed hydrologic characteristics and maps of the geologic units, chemical-quality characteristics of the ground water, an inventory of wells and springs as of 1966, and a description of the drainage problems associated with irrigated lands on the reservation. Reports by the Bureau of Indian Affairs (1971) and Hurlbut, Kersich, and McCullough Consulting Engineers (1975) describe the existing and potential water uses on the reservation. A report by HKM Associates (1979) evaluates and summarizes the hydrology, water supply, and quality of the surface-water resources on the reservation. Grasso and others (1995) describe and summarize physical, chemical, and biological data that were collected in 1992 and 1993 from irrigation drainage areas and wetlands of the Wind River Federal Irrigation Project area (pl. 1) on the reservation.

Numerous hydrologic and water-resources studies have been conducted in the Owl Creek and Wind River drainage basins, and Fremont and Hot Springs Counties. Parts of each of these drainage basins and counties are included in the reservation area. The eastern half of the reservation was discussed in a report of the hydrology of Coal Area 51, which includes part of both the Owl Creek and Wind River drainage basins (Peterson and others, 1987). Berry and Littleton (1961), Lowry and others (1976), and Ogle (1992) described the water resources and geology of the Owl Creek drainage basin, which includes the northeastern part of the reservation. Average annual runoff, measured in inches, was developed for the Wind River drainage basin by Oltman and Tracy (1949). Colby and others (1956) evaluated and summarized the sedimentation and chemical quality of surface waters in the Wind River drainage basin. The occurrence and characteristics of ground water in the Wind River drainage basin were summarized by Richter (1981). Other studies of the water resources and water supply of the Wind River drainage basin include Bishop and Spurlock Consulting Engineers (1962), Bureau of Reclamation (1966, 1981), and Whitcomb and Lowry (1968). Stoffer (1985) published a detailed bibliography and index of the geology of the Wind River structural basin, including reports on water resources in the basin. The water resources of Fremont County, which includes most of the reservation except for the northern part, were described and evaluated in a report by Plafcan and others (1995). The water resources of Hot Springs County, which includes the northern part of the reservation, were described and evaluated in a report by Plafcan and Ogle (1994).

Numbering System for Wells and Springs

The wells and springs listed in the report are identified by local numbers. A local number is based on the Federal township-range system of land subdivision. Inside the boundaries of the Wind River Indian Reservation and the Riverton Reclamation Withdrawal Area, this land subdivision system is referenced to the Wind River Meridian and Base Line system. Outside these boundaries, the land subdivision system is referenced to other meridians and base lines. An example of a local number is 1S-2E-14abc01 (fig. 2). The first segment of the local number (1S) denotes the township north or south of the Wind River Base Line. The second segment (2E) denotes the range east or west of the Wind River Meridian. The third segment (14abc) refers to the section number and the subdivision of that section. The subdivisions of a section are lettered a, b, c, and d in a counterclockwise direction beginning in the northeast quarter (a), then northwest (b), southwest (c), and southeast (d). The first letter following the section number denotes the quarter section (160 acres); the second letter denotes the quarter-quarter section (40 acres); and the third letter denotes the quarter-quarter-quarter section (10 acres). The fourth segment of the local number (01) is the sequential number after the lowercase letters that distinguishes that well from other wells assigned a local number in the same quarter-quarter section. Thus, the well with local number 1S-2E-14abc01 is the first well inventoried in the southwest quarter (1/4) of the northwest 1/4 of the northeast 1/4 of section 14, Township 1 south, Range 2 east (fig. 2).

Numbering System for Surface-Water Sites

Streamflow-gaging stations are sites on streams where systematic observations of hydrologic data are obtained. Gaging stations are identified with a unique eight-digit number assigned by the USGS. The first two digits of this number indicate the major drainage basin where the gaging station is located. All the numbers for gaging stations on or near the reservation start with "06", which indicates the Missouri River drainage basin. The remaining six digits indicate the downstream position in the major drainage basin and become progressively larger in a downstream direction. In addition, a simplified "site number" starting with the letter "G" was used in this report to identify gaging stations.

Miscellaneous surface-water sites are located on streams, canals, drains, and other open bodies of water where infrequent and miscellaneous types of hydrologic data are obtained. These sites are identified by a 15-digit site number that is based on the latitude and longitude of the site. The first six digits designate latitude of the site, the next seven digits designate longitude, and the last two digits are sequence numbers to distinguish between several sites that may be in close proximity of one another. A simplified "site number" starting with the letter "M" was used in this report to identify the miscellaneous surface-water sites.

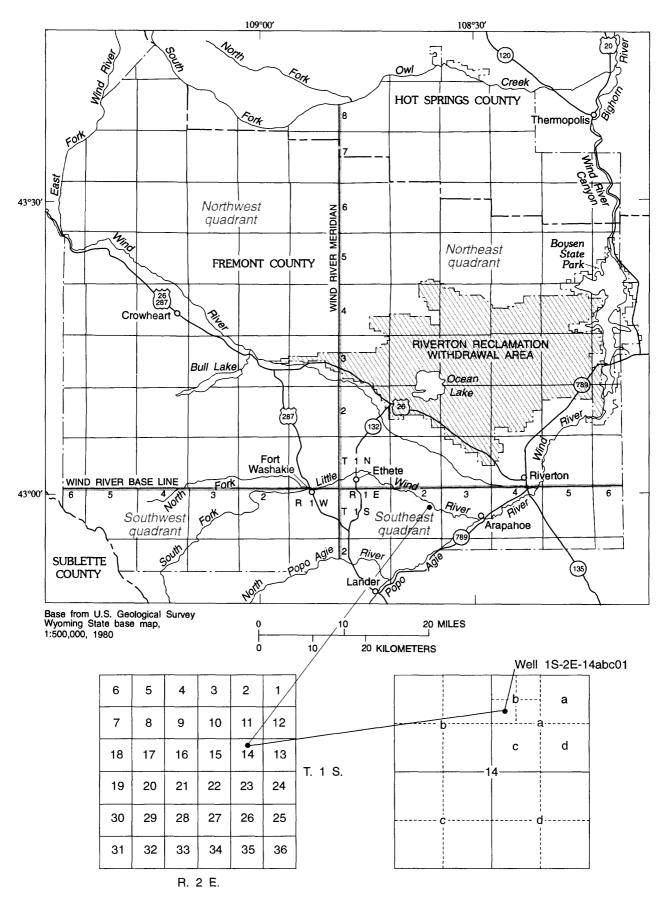


Figure 2. Numbering system for wells and springs in the Wind River Indian Reservation, Wyoming.

Acknowledgments

The authors would like to thank all the people who extended cooperation to the USGS in obtaining water-resources information, and collecting chemical-quality samples from wells, springs, streams, canals, and drains. Special appreciation is directed to the following individuals who provided detailed information on the water resources: James Sorenson, Eugene E. Meyers, and John T. Myers of the IHS office, Fort Washakie, Wyoming; Paul Rembold, Charles Dillahunty, Louis Twitchell, Ray Nation, Ruth Thayer, and Donald Crook of the BIA office, Fort Washakie, Wyoming; Mike Lajuenesse of Shoshone Utility Organization, Fort Washakie, Wyoming; Jerry Redman of Northern Arapahoe Utilities, Ethete, Wyoming; and James Malone and Roger Willenbrecht of Amoco Production Company. Special thanks also are extended to the Wind River Environmental Quality Commission of the Joint Business Council, Shoshone and Northern Arapahoe Tribes, Fort Washakie, Wyoming, for the guidance and support provided throughout the project.

DESCRIPTION OF THE STUDY AREA

The reservation is in west-central Wyoming (fig. 1). Most of the reservation is located in Fremont County, and the northeastern part is in Hot Springs County. The boundaries of the reservation have changed several times since the original area was established in 1868. The present reservation is about 68 miles (mi) east to west, about 65 mi north to south, and includes 1,993,000 acres (or 3,114 mi²). The eastern boundary of the reservation has been greatly modified from its original boundary by the Riverton Reclamation Withdrawal Area and the Boysen State Park (fig. 1). These two areas are not considered to be part of the reservation and have not been included in the study area of this report.

The reservation is home for about 8,000 Shoshone and Northern Arapahoe tribal members. About 85 percent of the reservation is held in trust by the U.S. Government for the Tribes or is owned by individual tribal members. Major unincorporated communities on the reservation include Arapahoe, Crowheart, Ethete, and Fort Washakie (fig. 1). Most of the remaining 15 percent of the reservation is private land, which includes the city of Riverton and private property located primarily in the Crowheart area and the southern part of the reservation.

Geographic Setting

Most of the reservation is in the western part of the Wind River Basin, which is a large structural basin. The southwestern part of the reservation extends along the eastern flank of the Wind River Range. The northern part of the reservation includes parts of the Absaroka Range and Owl Creek Mountains (fig. 3).

The Wind River drainage basin, which nearly coincides with the boundary of the Wind River structural basin, is the main drainage area on the reservation (fig. 3). About 86 percent of the reservation lies in this drainage basin. Most of the remaining 14 percent is in the Owl Creek drainage basin and several small drainage basins of minor tributaries to the Bighorn River (fig. 3).

The physiography of the reservation is diverse, consisting of alpine, glaciated, and mountainous terrain along the northern and southwestern edges of the reservation and foothills, high plateaus, rugged badlands, plains, and terraced-stream valleys in the other parts of the reservation. Land-surface altitudes range from about 4,400 feet (ft) at the northern end of the Wind River Canyon in the Owl Creek Mountains to about 13,000 ft in the Wind River Range. In the central part of the reservation, the altitude ranges from about 4,800 to 6,000 ft.

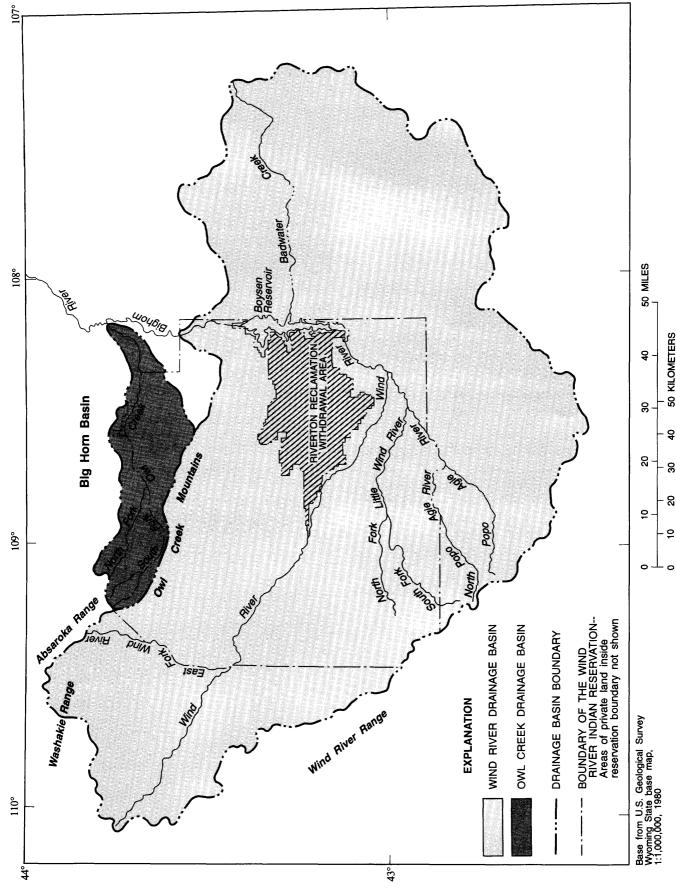


Figure 3. Location of the Wind River and Owl Creek drainage basins, Wyoming.

Climate

The climate of the reservation ranges from desert in the central part to alpine in the bordering mountain ranges (Martner, 1986, p. 3-6). Annual precipitation ranges from 6 to 8 in. in the central part of the reservation and from 10 to 20 in. along the flanks of the mountain ranges. Precipitation is greater than 30 in. in the upper zones of the Owl Creek Mountains and Absaroka Range and is greater than 50 in. near the top of the Wind River Range (Hurlbut, Kersich, and McCullough Consulting Engineers, 1975, fig. III.2, p. III-5). Most of the October through March precipitation occurs as snow. Average annual snowfall is less than 20 in. in the lower elevations, ranges from 40 to 80 in. in the Owl Creek Mountains, and is greater than 150 in. in the Wind River Range (Martner, 1986, p. 81). Most of the mountain snowfall is stored as snowpack. Snowmelt is a major source of streamflow on the reservation during the spring and summer. Mean-annual precipitation and temperature data for eight weather stations on or near the reservation are listed in table 1 (Martner, 1986; Owenby and Ezell, 1992). The locations of these weather stations are shown in figure 1.

Table 1. Mean-annual precipitation and mean-annual temperature for selected weather stations on or near the Wind River Indian Reservation, Wyoming

[Site number, site numbers used in this report. Altitude of land surface, in feet above sea level; deg, degrees; min, minutes; ft, feet; in, inches, ^oF, degrees Fahrenheit; WSO, Weather Service Office; AP, airport]

Site number (fig. 1)	Weather station	Latitude (deg-min)	Longitude (deg-min)	Altitude of land surface (ft)	Period of record	Mean- annual precipitation (in.)	Mean- annual temperature (°F)
C1	Anchor Dam	43-40	108-50	6,460	1961-79	15.2	41.3
C2	Boysen Dam	43-25	108-11	4,642	1961-90	9.29	47.4
C3	Burris	43-22	109-17	6,140	1961-90	8.93	44.3
C4	Diversion Dam	43-14	108-56	5,575	1961-90	8.97	44.9
C5	Fort Washakie	42-59	108-53	5,550	1951-79	11.9	42.2
C6	Lander WSO AP	42-49	108-44	5,370	1961-90	13.0	46.0
C7	Pavillion	43-15	108-41	5,440	1961-90	7.53	44.3
C8	Riverton	43-01	108-23	4,950	1961-90	7.74	42.6

Geologic Setting

The geologic structure of the reservation consists of the Wind River Basin, which is a large structurally complex basin bounded on the north and southwest by upfolded and faulted mountain ranges. The structural relief from the top of the mountains to the bottom of the structural basin is about 30,000 ft. Keefer (1970) provides a detailed description of the geologic structure and history of the Wind River Basin and surrounding mountain ranges. Structure-contour maps and geologic cross sections of the reservation are contained in reports by Keefer (1970, pl. 2) and McGreevy and others (1969, pl. 2).

Rocks from all geologic periods except those of Silurian age are present within the reservation. Igneous and metamorphic basement rocks of Precambrian age are exposed on the upper parts of most of the mountain ranges and underlie the sedimentary rocks in the basin. Rocks of Paleozoic and Mesozoic age crop out along the lower flanks of the mountain ranges, on numerous anticlines in the basin, and are buried in the central part of the basin. These rocks generally dip basinward at angles ranging from 10 to 15 degrees along the flanks of the Wind River Range, and are vertical to overturned along the margins of anticlines and along the northern mountains. Geologic units of Tertiary and Quaternary age crop out in most of the central part of the basin and consist primarily of the Wind River Formation of Tertiary age and deposits of Quaternary age such as floodplain alluvium, slope wash and alluvium, terrace deposits, and glacial deposits. Tertiary volcaniclastic rocks of the Absaroka Range crop out in the northwestern part of the reservation.

Generalized geology of the reservation is shown in figure 4. For a more detailed description of the geology of the reservation the reader is directed to McGreevy and others (1969, pl. 2). The major geologic units and percentages of reservation area in each generalized geologic-map unit is summarized in table 2. Additional detailed information on the physical and lithologic characteristics of the geologic units listed in table 2 is provided in reports by Keefer (1965, 1972), Keefer and Van Lieu (1966), McGreevy and others (1969, p. I13-I21), and Refolo (1983, p. 6-44).

WATER USE

Ground-water and surface-water uses are extensive and diverse throughout the reservation. Principal water uses consist of public supply, domestic, agricultural, industrial, recreational, and fisheries.

Both ground water and surface water provide water sources for public-supply and private domestic uses on the reservation. Wells furnish water to most of the public water-supply systems on the reservation, which include the Arapahoe, Arapahoe Industrial Park, Trout Creek, and Boulder Flats community water-supply systems. Surface water diverted from the South Fork Little Wind River supplies the Fort Washakie community. A streambed infiltration system on the Little Wind River supplies water to the Ethete community. These public water-supply systems are operated by various tribal-based organizations. The site location and estimated water use for these systems are summarized in table 3. Water-use information for the City of Riverton and smaller public water-supply systems on the reservation are listed in Richter (1981, p. 32-37). Ground water is the principal water source for private domestic use on the reservation.

Agricultural water use includes water for irrigation of crops and water used in beef, dairy, poultry, and other livestock production. Irrigation is the most common use of water on the reservation. Except for several irrigation wells in the Riverton area and Owl Creek drainage basin, streamflow is the only source of irrigation water. Because of recent water-rights adjudication on the reservation, the use of irrigation water has been evaluated and summarized in detail (Roncalio, 1982). The major water use on the reservation is for irrigation in the Wind River Federal Irrigation Project area (pl. 1). About 170,000 acre-ft of water is diverted from various streams each year to irrigate an average of 28,000 acres in the Wind River Federal Irrigation Project area (Donald Crook, U. S. Bureau of Indian Affairs, oral commun., 1989). Water from streams, springs, and wells also is used for livestock.

The principal industrial water user is the petroleum industry. The reservation has 15 oil-and-gas fields. Ground water is withdrawn from most oil-and-gas fields as a by-product of oil production and for secondary recovery by water-flooding. Most of the ground water withdrawn is re-injected into wells at the fields, but some of the water is released into surface-water channels and ponds.

Recreation and fisheries water use on the reservation are diverse and generally nonconsumptive. Sources for these uses are streams, springs, lakes, and reservoirs. Washakie Mineral Hot Springs, near Ethete, has provided water for a public swimming-pool and bath facility.

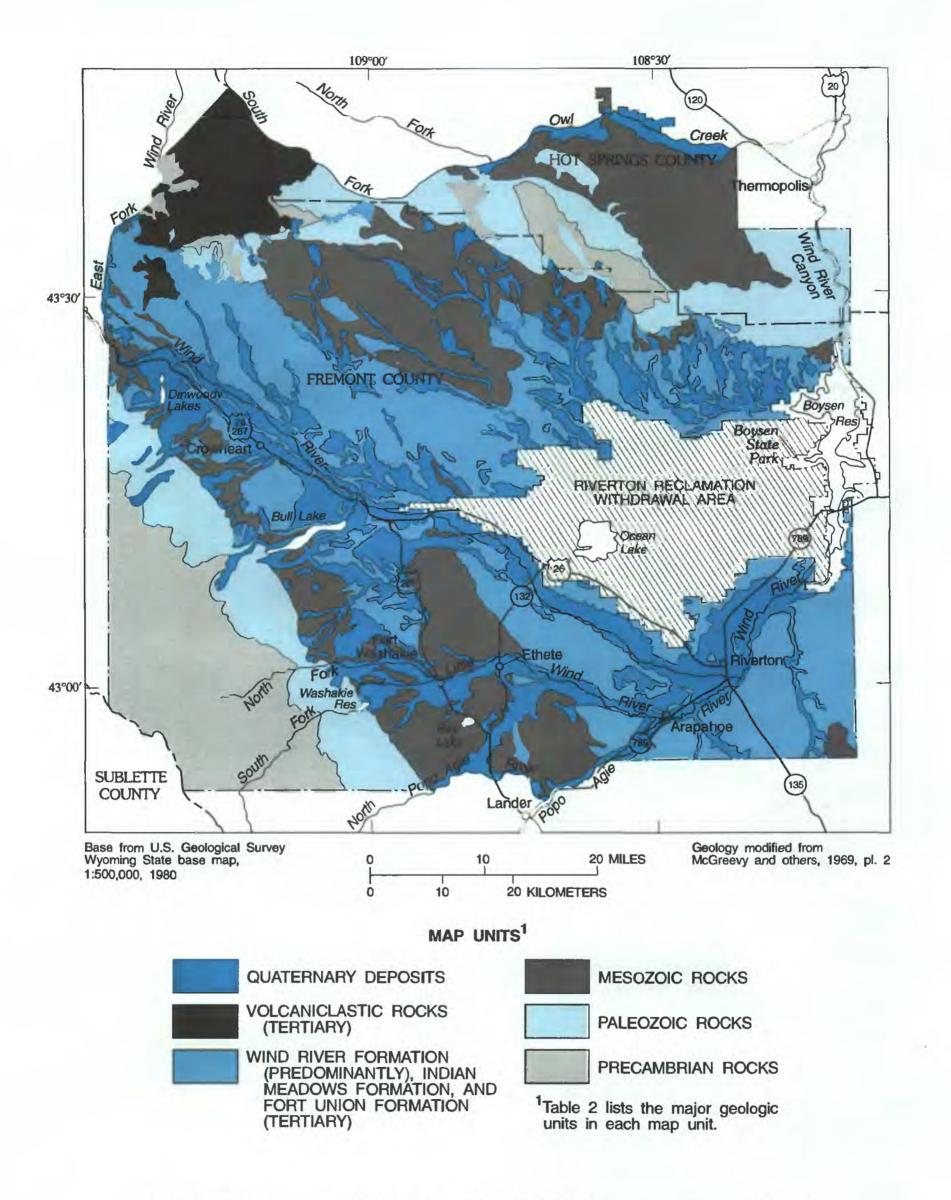


Figure 4. Generalized geology of the Wind River Indian Reservation, Wyoming.

 Table 2.
 Major geologic units and percentage of reservation area included in each generalized geologic-map unit, Wind River Indian Reservation,

 Wyoming

Generalized geologic-map unit (fig. 4)	Percentage of the Wind River Indian Reservation area within generalized geologic-map unit	Major geologic units and age ¹
Quaternary deposits	20.8	Flood-plain alluvium, slope wash and alluvium (Holocene and Pleistocene) ²
		Terrace deposits (Holocene and Pleistocene) ²
		Landslide and colluvial deposits (Holocene and Pleistocene)
		Travertine deposits (Holocene and Pleistocene)
		Glacial deposits (Holocene and Pleistocene) ²
Tertiary volcaniclastic rocks ²	4.3	Wiggins Formation [Thorofare Creek GroupAbsaroka Volcanic Supergroup] (Eocene)
		Tepee Trail Formation [Thorofare Creek GroupAbsaroka Volcanic Supergroup] (Eocene)
		Aycross Formation [Thorofare Creek GroupAbsaroka Volcanic Supergroup] (Eocene)
Tertiary rocks except volcaniclastic rocks	26.7	Wind River Formation (Eocene) ²
		Indian Meadows Formation (Eocene)
		Fort Union Formation (Paleocene)
Mesozoic rocks	21.5	Lance Formation (Upper Cretaceous)
		Meeteetse Formation (Upper Cretaceous)
		Mesaverde Formation (Upper Cretaceous)
		Cody Shale (Upper Cretaceous) ²
		Frontier Formation (Upper Cretaceous) ²
		Mowry Shale and Thermopolis Shales of Colorado Group (Upper and Lower Cretaceous)
		Cloverly Formation (Lower Cretaceous) ²
		Morrison Formation (Upper Jurassic)
		Sundance Formation (Upper and Middle Jurassic)
		Gypsum Spring Formation (Middle Jurassic)
		Nugget Sandstone (Jurassic (?) and Triassic $(?)$) ²
		Popo Agie Formation [Chugwater Group] ² (Upper Triassic)
		Crow Mountain Sandstone [Chugwater Group] ² (Upper Triassic)

 Table 2. Major geologic units and percentage of reservation area included in each generalized geologic-map unit, Wind River Indian Reservation,

 Wyoming--Continued

Generalized geologic-map unit (fig. 4)	Percentage of the Wind River Indian Reservation area within generalized geologic-map unit	Major geologic units and age ¹
Mesozoic rocksContinued		Alcova Limestone [Chugwater Group] ² (Upper Triassic) Red Peak Formation [Chigwater Groun] ² (Lower Triassic)
		Dinwoody Formation (Lower Triassic)
Paleozoic rocks	14.3	Phosphoria Formation and related rocks (Permian) ²
		Tensleep Sandstone (Upper and Middle Pennsylvanian) ²
		Amsden Formation (Middle and Lower Pennsylvanian and Upper Mississippian)
		Madison Limestone (Mississippian) ²
		Darby Formation (Upper Devonian)
		Bighorn Dolomite (Upper Ordovician)
		Gallatin Limestone (Upper Cambrian)
		Gros Ventre Formation (Upper and Middle Cambrian)
		Flathead Sandstone (Middle Cambrian)
Precambrian rocks	12.4	Precambrian rocks (Proterozoic and Archean)

¹Modified from McGreevy and others (1969, pl. 2), Love and Christiansen (1985), Love, Christiansen, and Ver Ploeg (1993), and Peter R. Stevens, U.S. Geological Survey, written commun., 1994.

²The hydrologic and water-quality characteristics of ground water from these major geologic units, volcaniclastic rocks, and the Chugwater Group are summarized and evaluated in this report.

Table 3. Source of water and water-use data for selected public water-supply systems, Wind River Indian Reservation, Wyoming

[Source of water: wells are identified with local well number that is described in this report; gal/d, gallon per day]

Public water- supply system	Source of water	Estimated average daily production (gal/d)	Source of production data
Arapahoe	Two wells (1S-3E-11dcd01, 1S-3E-11dcd02) completed in the Wind River Formation of Tertiary age	300,000	Jerry Redman, Northern Arapahoe Utilities, oral commun., 1990
Arapahoe Industrial Park	One well (1S-3E-23bdd03) completed in the Wind River Formation of Tertiary age	67,000	Jerry Redman, Northern Arapahoe Utilities, oral commun., 1990
Trout Creek	Two wells (1S-2W-24dca01, 1S-2W-24dcb02) completed in the Nugget Sandstone of Jurassic (?) and Triassic (?) age	30,000	Mike Lajuenesse, Shoshone Utility Organization, oral commun., 1990
Boulder Flats	Two wells (2S-1W-13adb01, 2S-1W-13adb02) completed in flood-plain alluvium of the North Fork Popo Agie River	16,000	Eugene E. Myers, Indian Health Services, oral commun., 1990
Fort Washakie	Surface-water diversion from South Fork Little Wind River about 3.1 miles west of Fort Washakie	700,000	Mike Lajuenesse, Shoshone Utility Organization, oral commun., 1990
Ethete	Streambed infiltration from Little Wind River about 1.3 miles west of Ethete	380,000	Jerry Redman, Northern Arapahoe Utilities, oral commun., 1990

The various water uses for the inventoried wells are summarized in the following table. Domestic use (private water-supply systems) is the most common water use for wells on the reservation.

Water use	Number of wells	Percentage of total wells
Public supply	24	1.8
Domestic	674	49.7
Irrigation	10	0.7
Livestock	105	7.7
Industrial	32	2.4
Unused	386	28.4
Unknown	126	9.3
Total	1,357	100.0

GROUND-WATER RESOURCES

Ground water usually is derived from infiltration of precipitation or from surface-water seepage. Ground water moves through the geologic units from recharge areas to discharge areas such as springs, gaining streams, or other geologic units at rates dependent on the gradient and permeability of the geologic units. Heath (1983) provides an excellent overview on the basic hydrology of ground water.

Ground-water resources on the reservation occur in many different geologic units and as springs flowing from these units. Ground water provides water for public-supply, domestic, livestock, and industrial uses on the reservation. Ground water is a potential source of additional supply for irrigation on the reservation.

Hydrologic and water-quality characteristics of ground water from the following major geologic units (table 2) are evaluated and summarized in this report: flood-plain alluvium, slope wash and alluvium, terrace deposits, glacial deposits, volcaniclastic rocks, Wind River Formation, Cody Shale, Frontier Formation, Cloverly Formation, Nugget Sandstone, Chugwater Group, Phosphoria Formation and related rocks, Tensleep Sandstone, and Madison Limestone. These 14 major geologic units were evaluated because they supply most of the ground water used on the reservation or have the potential to yield substantial quantities of ground water that is suitable for human consumption and other uses.

Quaternary Deposits

Quaternary deposits containing ground water consist of flood-plain alluvium, slope wash and alluvium, terrace deposits, and glacial deposits. Quaternary deposits provide water for domestic and public-supply uses on the reservation. Inventory records were compiled for 507 wells completed in the Quaternary deposits on the reservation. Selected ground-water data for wells completed in Quaternary deposits are listed in table 4. Most of the inventoried wells completed in these deposits are less than 50 ft deep.

Flood-plain Alluvium

Flood-plain alluvium consists mostly of unconsolidated deposits of silt, sand, gravel, cobbles, and boulders. These recent deposits occur as valley fill and adjacent low terraces in most of the major stream valleys on the reservation. The deposits range from 5 to more than 100 ft in thickness but are generally less than 40 ft thick (McGreevy and others, 1969, p. 149). These deposits in four drainage basins are discussed separately because of differences in the extent of the deposits and the lithology of the underlying geologic units. The Wind River flood-plain alluvium generally is thicker and more laterally extensive than other Quaternary deposits on the reservation and is underlain by the Wind River Formation. Most of the middle one-third of the Little Wind River flood-plain alluvium and the Popo Agie River flood-plain alluvium are underlain by the Cody Shale and Frontier Formation of Cretaceous age, which both contain substantial amounts of soluble minerals. Most of the Owl Creek flood-plain alluvium on the reservation is underlain by the Cody Shale and Frontier Formation.

Inventory records were compiled for 361 wells completed in the flood-plain alluvium deposits on the reservation. Selected ground-water data for these inventoried wells are listed in table 4. Well depths range from 5 to 135 ft, with a median depth of 30 ft.

Water levels in wells completed in the flood-plain alluvium were evaluated on the basis of water-level measurements in 250 wells during 1948-91. Water levels ranged from land surface to 41.6 ft below land surface. with a median value of 8.3 ft below land surface. Seasonal recharge from seepage of irrigation water from surface-water sources caused substantial seasonal water-level fluctuations in wells in some areas. Typically, water levels in wells located near irrigated lands are the highest during the irrigation season, which generally is from June to September, and the lowest before irrigation is started. For example, water levels in four wells (1N-2W-25dbc01, 1N-2W-36dda01, 1N-2W-35adc04, 1N-2W-26ccc01) completed in flood-plain alluvium in the Little Wind River drainage basin and near irrigated lands, had seasonal water-level declines of 6.2, 7.8, 8.6, and 17.5 ft respectively, between July 1990 (irrigation season) and May 1991 (before irrigation).

In some areas on the reservation, water levels in wells completed in the flood-plain alluvium typically are less than 5 ft below land surface for the entire year. These high water levels occur in two general areas: south of Fort Washakie and east of Ethete. In both areas, the flood-plain alluvium generally is less than 25 ft thick, is not near major river channels, and is underlain by the Cody Shale.

[Well depth range and median, in feet below land surface. Type of well log: d, driller; g, geologist. Units of measurement: ft, feet; gal/min, gallon per minute; (gal/min)/ft, gallon per minute per foot; Table 4. Summary of selected ground-water data for wells completed in Quaternary deposits, Wind River Indian Reservation, Wyoming

					, Xir	Yield	Number of	Specific capacity	capacity
	,	Well depth	Number		(gal	(gal/min)	wells with	[(gal/min)/ft]	nin)/ft]
Geologic unit ¹	Number of wells inventoried	range and [median] (ft)	and type of well logs available	Number of wells with yield data	Range	Median	specific- capacity data	Range	Median
Flood-plain alluvium, all drainage basins	361	5-135 [30]	188 d, 4 g	123	4-60	15	62	0.2-40	3.0
Wind River flood- plain alluvium	118	5-80 [25]	30 d, 4 g	12	5-50	20	7	0.8-8.0	2.5
Little Wind River flood-plain alluvium	202	9-135 [32]	148 d	106	4-60	15	89	0.2-40	2.9
Popo Agie River flood-plain alluvium	17	12-47 [31]	p 9	ν.	10-60	20	4	3.5-12	6.7
Owl Creek flood- plain alluvium	24	12-90 [46]	4 d	;	1	;	!	1	ŀ
Slope wash and alluvium	54	10-310 [36]	26 d, 3 g	19	4-20	0.9	8	0.4-15	4.3
Terrace deposits	87	5-200 [36]	29 d, 3 g	13	2-50	20	10	0.1-40	3.8
Glacial deposits	5	10-124 [45]	2 d	2	15-20	1	2	0.7-20	1

¹For flood-plain alluvium geologic units, geographic location (drainage area) also is included.

--, no data or not applicable]

Yields from wells completed in the flood-plain alluvium were estimated on the basis of driller's wellacceptance-test and pumping-test data that were collected during 1963-88. The water-yield data from wellacceptance tests consisted of yield measurements from 123 wells and specific-capacity determinations from 79 wells. Yield is the constant or final pumping rate in gallons per minute (gal/min) at which the wellacceptance test was conducted. Specific capacity is the yield per unit drawdown and is reported in gallons per minute per foot [(gal/min)/ft]. This value is determined by dividing the constant or final pumping rate by the total drawdown during the well test. Heath (1983, p. 58-59) provides a good description about well-acceptance tests and how they should be conducted. The pumping period for most of these well-acceptance tests was 2 hours or longer. Yields ranged from 4 to 60 gal/min, with a median value of 15 gal/min. Specific capacities ranged from 0.2 to 40 (gal/min)/ft, with a median value of 3.0 (gal/min)/ft (table 4).

Five pumping tests were conducted in 1965 and 1966 and the results are reported in McGreevy and others (1969, p. I30). Specific capacities from these five pumping tests ranged from 1 to 65 (gal/min)/ft.

Slope Wash and Alluvium

Slope wash and alluvium consists of slope wash, slope wash with interbedded or underlying alluvium, and flood-plain alluvium on smaller perennial, intermittent, and ephemeral streams. Slope wash is defined as soil and rock material that has been moved down a slope by mass wasting assisted by running water not confined to fluvial channels (Bates and Jackson, 1980, p. 588). Slope wash consists mostly of fine-grained unconsolidated deposits of clay, silt, and sand. Alluvium consists of clay, silt, sand, gravel or other unconsolidated material deposited during recent geologic time by a stream or other body of running water as a sediment in the bed of a stream or on the floodplain or delta, or as a fan at the base of a mountain (Bates and Jackson, 1980, p. 46). This geologic unit is scattered throughout the reservation and ranges from about 5 to 80 ft in thickness (McGreevy and others, 1969, p. I47).

Inventory records were compiled for 54 wells completed in the slope wash and alluvium on the reservation. Selected ground-water data for these inventoried wells are listed in table 4. Most of these wells are in the Mill Creek area. Other wells completed in this geologic unit are in the upper Muddy Creek, Sage Creek, Beaver Creek, and Kirby Draw drainage areas. Well depths range from 10 to 310 ft, with a median depth of 36 ft.

Water levels in wells completed in this geologic unit were evaluated on the basis of water-level measurements in 30 wells during 1948-91. Water levels ranged from 1.0 to 27.4 ft below land surface with a median value of 7.0 ft below land surface. Ground water in this unit responds to seasonal water-level fluctuations caused by irrigation recharge. Wells completed in slope wash and alluvium in nonirrigated areas of smaller or intermittent stream valleys usually have small (less than 3 ft) water-level fluctuations. Water-level fluctuations in these wells usually correspond to seasonal changes in streamflow. For example, water levels in an observation well (1S-5E-11bdd01), 34 ft deep, about 300 ft from Kirby Draw (an ephemeral stream) were measured 80 times during 1965-66, 1970-83, and in 1991. Water levels in this well typically had annual waterlevel fluctuations of less than 3 ft, with a mean water-level of 21.0 ft below land surface. The highest water levels in this well generally occur each year between May and early June, a time period that corresponds to maximum streamflows in Kirby Draw.

Yields of water from wells completed in slope wash and alluvium were evaluated on the basis of 19 yield measurements and 8 specific-capacity determinations from well-acceptance tests conducted during 1963-89. Yields ranged from 4 to 20 gal/min, with a median value of 6 gal/min. Specific capacities ranged from 0.4 to 15 (gal/min)/ft, with a median value of 4.3 (gal/min)/ft (table 4).

Terrace Deposits

The terrace deposits consist of unconsolidated deposits of silt, sand, gravel, cobbles, and boulders and usually appear as bench or steplike features. These recent deposits are present on the edges of the major river valleys and on the lower flanks of the Wind River Range on the reservation. This unit is usually less than 50 ft thick but may be as much as 200 ft thick (Richter, 1981, p. 87).

Inventory records were compiled for 87 wells completed in terrace deposits. Selected ground-water data for these inventoried wells are listed in table 4. Most of the wells are northeast of the City of Riverton, in the Crowheart area, and in the Boulder Flats area south of Ray Lake. All of these areas are extensively irrigated with surface water. Well depths range from 5 to 200 ft, with a median depth of 36 ft.

Water-levels in wells completed in this geologic unit were evaluated on the basis of water-level measurements in 59 wells during 1949-91. Water levels ranged from flowing conditions to a depth of 56.9 ft below land surface, with a median value of 14.7 ft below land surface. Water levels in the terrace deposits also change substantially because of recharge by irrigation water.

In the Boulder Flats area, numerous wells completed in this geologic unit have water levels less than 5 ft below land surface during the entire year. These wells are in areas where the terrace deposits are usually less than 25 ft thick and are underlain by the Cody Shale. Water levels in one observation well (2S-1E-06ddd01), 60 ft deep, were measured 79 times during 1965-66, 1970-83, and in 1991. Water levels in this well ranged from land surface to 4.7 ft below land surface, with a mean value of 2.1 ft below land surface.

Yields of water from wells completed in the terrace deposits were evaluated on the basis of 13 yield measurements and 10 specific-capacity determinations from well-acceptance tests conducted during 1976-89. Yields ranged from 2 to 50 gal/min, with a median value of 20 gal/min. Specific capacities ranged from 0.1 to 40 (gal/min)/ft, with a median value of 3.8 (gal/min)/ft (table 4). Richter (1981, p. 87-88) reported that selected wells completed in terrace deposits in the Lander and Riverton areas had maximum yields of 150 gal/min and a maximum permeability of 1,000 (gal/d)/ft ².

Springs flowing from this unit usually are located in the coarse-grained layers or at the base of the terrace deposits. Most springs have flow rates less than 2 gal/min and usually flow in response to recharge by irrigation return flow.

Glacial Deposits

Glacial deposits consist of unconsolidated glacial till and outwash deposits. Glacial deposits are a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders ranging widely in size. Glacial deposits occur in the areas of Dinwoody Lakes and Bull Lake and along the upper reaches of the North and South Forks Little Wind River.

Inventory records were compiled for five wells completed in glacial deposits in the area of Dinwoody Lakes. Selected ground-water data for these inventoried wells are listed in table 4. Well depths range from 10 to 124 ft, with a median depth of 45 ft. Yields of water of 15 and 20 gal/min were measured, and specific capacities of 0.7 and 20 (gal/min)/ft were determined for two wells.

Altitude and Configuration of the Water Table for Two Selected Areas

The altitude and configuration of the water table in Quaternary deposits for two selected areas on the reservation are shown on plates 2 and 3. These areas were studied because this is where major communities on the reservation are located and ground-water contamination is a concern. Most of the Quaternary deposits in these two areas are assumed to be hydraulically connected. Plate 2 contains water-table contours and depth to water in the flood-plain alluvium, slope wash and alluvium, and terrace deposits in the Little Wind River drainage basin, and in the slope wash and alluvium, and terrace deposits in the Mill Creek drainage basin, a tributary of the Little Wind River. Plate 3 contains the water-table contours and depth to water in the terrace deposits and the Meadow Creek flood-plain alluvium in the Crowheart area from Little Sand Draw to Dry Creek.

The water-table contours shown on plates 2 and 3 are based primarily on water levels measured at selected wells completed in Quaternary deposits in the two areas. The number of wells measured and the time period of water-level measurements in the two areas are as follows: (1) Little Wind River and Mill Creek drainage basins—128 wells, April 23 to May 17, 1991; (2) the Crowheart area—23 wells, May 14-17, 1991 (Daddow, 1992). Water-surface altitudes of most of the perennial stream reaches in the selected areas were used as control for mapping the water-table contours. These perennial reaches were assumed to be hydraulically connected with the water table. The altitude of land surface at all the wells and the water surface of perennial stream reaches were determined from 7.5-minute topographic quadrangle maps. When water levels were measured in the selected areas, several major irrigation canals had been recently filled with water, but irrigation of agricultural lands had not started in any of these areas. Water-level measurements from two wells completed in the Cody Shale and eight wells completed in the Wind River Formation also were used as control to delineate the water-table contours in the Quaternary deposits in the Little Wind River drainage basin (pl. 2). Water-level measurements from five wells completed in the Wind River Formation also were used as control to determine water-table contours in the Quaternary deposits in the Crowheart area (pl. 3). These wells were assumed to be hydraulically connected with the overlying Quaternary deposits because the wells are shallow (mostly less than 90 ft deep) and water levels in these wells were similar to water levels in wells completed in the Quaternary deposits.

Ground water that is unconfined (under water-table conditions) moves from high water-level altitude to lower water-level altitude, generally perpendicular to the water-table contours (Heath, 1983, p. 20-23). The water-table contours on plates 2 and 3 show that most of the perennial stream reaches are gaining reaches (watertable contours bend upstream) in the two selected areas, which indicates that when water levels were measured, the reaches probably were receiving water from ground-water sources. Ground-water movement in the Crowheart area (pl. 3) generally is a subdued reflection of the slope of the land surface. Flood-plain alluvium of Meadow Creek was included in the water-table contour map of the Crowheart area (pl. 3) because it is topographically similar to the adjacent terrace deposits and assumed to be hydraulically connected to the water table in the adjacent terrace deposits. Flood-plain alluvium of Willow Creek was not included in the water-table contour map of the Crowheart area because the flood-plain valley of this stream is substantially entrenched and separated from the terrace deposits by outcrops of the Wind River Formation.

Tertiary Rocks

The hydrologic characteristics of the following Tertiary rocks were evaluated and summarized: volcaniclastic rocks and the Wind River Formation of Eocene age. Because of the lack of well and spring data, hydrologic characteristics of the following rocks were not evaluated: Indian Meadows Formation of Eocene age and Fort Union Formation of Paleocene age. Physical and hydrologic characteristics of these rocks are described in McGreevy and others (1969, p. I14-I15).

Volcaniclastic Rocks

The major volcaniclastic rocks consist of the Wiggins, Tepee Trail, and Aycross Formations, which have similar lithologies consisting generally of a mixture of volcaniclastic sandstone, conglomerate, mudstone, shale, tuff, and lava flows (Bown, 1982, p. 1). These rocks are present in the northwest corner of the reservation (fig. 4) and overlie the Wind River Formation, Paleozoic rocks, and Precambrian rocks.

On the basis of onsite investigations and available inventory records, no wells have been identified as completed in the volcaniclastic rocks. Flow rates of 8, 14, and 37 gal/min were measured in October 1989 at three springs flowing from the Tepee Trail Formation (table 5). Numerous other springs flowing from the Tepee Trail Formation were observed. Some of these other springs are the major source of water for small streams in the area.

Table 5. Summary of selected ground-water data for wells completed in and springs flowing from Tertiary, Mesozoic, and Paleozoic rocks on or near the Wind River Indian Reservation, Wyoming

[Type of site: w, well; s, spring. Well depth range and median, in feet below land surface. Type of well log: d, driller; g, geologist. Units of measurement: ft, feet; gal/min, gallon per minute; (gal/min)/ft, gallon per minute per foot; --, no data or not available]

Geologic unit ir Geologic unit ir Volcaniclastic rocks Tepee Trail Formation Wind River Formation	and type of sites				,		:		
Volcaniclastic rocks Tepee Trail Formation Wind River Formation	וואפוווסוופת	Well depth range and [median] (ft)	and type of well logs available	of sites with yield data	Range	Median	specific- capacity data	Range	Median
Volcaniclastic rocks Tepee Trail Formation Wind River Formation			Terti	Tertiary rocks					
Wind River Formation	3 s	;	;	3 s	8-37	14	1	ŀ	1
وادماع ، المركز	w 809	37-994 [190]	305 d, 21 g	266 w	0.1-350	20	151	0.04-23	0.4
Cod: Cholo			Meso	Mesozoic rocks					
Cody strate	24 w	33-1,010 [85]	12 d	w 6	1.5-20	5.0	9	0.03-1.4	0.4
Frontier Formation	52 w 2 s	31-3,760 [94]	33 d 	20 w 2 s	0.5-40 0.6-1.2	6.5	11	0.1-3.3	0.5
Cloverly Formation	7 w 1 s	26-182 [150] 	7 d	» •	5-20	13.5	4	0.3-4	2.7
Nugget Sandstone	5 w	40-7,240 [63]	4 d	4 w	10-90	55	3	3.3-8.2	4.0
Chugwater Group	6 w 5 s	37-101 [66]	5 d 	5 w 4 s	9-20 2-75	18 7.0	4	1.0-4.5	1.2
			Paleo	Paleozoic rocks					
Phosphoria Formation and related rocks	13 w 1 s	200-6,750 [1,720]	2 d 	1 w		1 1	; ;	1 1	1 1
Tensleep Sandstone	3 w 1 s	450-900 [700]	1 1	3 w 1 s	14-75 332	42	1 1	1 1	1 1
Madison Limestone	3 w 1 s	1,400-4,210 [2,930] 	1 d 	3 w 1 s	260-900 94	700	: :	t i	: :

Wind River Formation

The Wind River Formation is exposed in most of the central part of the reservation (fig. 4) and is the major source of drinking water for domestic and public-supply uses. The Wind River Formation was deposited following uplift of the Wind River and Washakie Ranges and the Owl Creek Mountains. The formation is composed of erosional debris of mixed lithology from these uplift areas. This erosional debris was deposited as alluvial fans near the mountains. The debris also was deposited in depressional areas and as stream-valley fill and broad flood plains in the central part of the reservation (Seeland, 1978, p. 5). The depositional pattern of the erosional material has resulted in a formation with variable lithology and permeability throughout the Wind River Basin.

The Wind River Formation consists of sandstone, conglomerate, shale, and mudstone with small quantities of bentonite, tuff, and limestone (McGreevy and others, 1969, p. 142). This geologic unit varies greatly, ranging in thickness from about 100 ft along the mountain flanks to about 5,000 ft in the central part of the reservation. The Wind River Formation is complex in its stratigraphy and contains several major facies or sequences. McGreevy and others (1969, p. I42-45) describe the major sequences of the Wind River Formation in the eastern part of the reservation as an upper sequence that is generally fine grained and about 800 ft thick; a middle coarse-grained sequence about 1,000 ft thick; and a fine-grained, basal sequence about 700 ft thick. Along the flanks of the Wind River Range in the western part of the reservation, this formation is about 200 ft thick and is composed of boulder conglomerate interbedded with arkosic sandstone. East of the mountain flanks, this formation is about 2,000 ft thick with a variegated claystone and siltstone sequence underlain by an arkosic sandstone and conglomerate sequence (Refolo, 1983, p. 41-43). Many coarse-grained permeable sandstone and conglomerate deposits are found in the Wind River Formation, however, most of these deposits are lenticular, discontinuous, and separated by confining shale, mudstone, and siltstone units (Richter, 1981, p. 82; McGreevy and others, 1969, p. I43, fig. 13).

Permeability is an important physical property controlling the overall water-yield potential of the Wind River Formation, and the Mesozoic and Paleozoic geologic units. Permeability is affected by the lithology, sedimentary structure and deposition, and tectonic deformation of the rocks. In general, porosity and intergranular permeability are relatively large in sandstone, limestone, and dolomite, and are small in shale and igneous and metamorphic rocks. Tectonic deformation during structural uplift causes regional fracturing that creates faults, fractures, and joints in the rocks. These deformed zones can provide both lateral and vertical connections that substantially increase the overall permeability (Richter, 1981, p. 61-62).

Inventory records were compiled for 608 wells completed in the Wind River Formation. Selected groundwater data from these inventoried wells are listed in table 5. Most of these wells are completed in mostly permeable, lenticular, and discontinuous sandstone deposits. Well depths range from 37 to 994 ft, with a median depth of 190 ft.

Wells completed in the Wind River Formation yield water from both unconfined and confined sandstone layers. Wells less than 90 ft deep usually yield water from unconfined sandstone layers recharged primarily by water from overlying Quaternary deposits and irrigation return flow. About 150 shallow wells (less than 90 ft deep) are completed in the Wind River Formation, and most of the wells are located in the major flood-plain valleys or on terraces. Water-levels in shallow wells were evaluated on the basis of water-level measurements in 93 wells during 1938-91. Water levels ranged in depth from land surface to 84 ft below land surface, with a median depth of 15.8 ft below land surface.

Wells completed in the Wind River Formation and more than 100 ft deep usually yield ground water from confined sandstone layers. These layers usually are recharged by surface water or by infiltration of precipitation. About 440 deep wells (more than 100 ft deep) are completed in the Wind River Formation and most of the wells are completed as open holes or with perforated casing so that water from multiple confined sandstone layers is obtained. Water levels in deep wells were evaluated on the basis of water-level measurements in 179 wells during 1942-91. Water levels ranged from flowing conditions to 533 ft below land surface, with a median depth of 45.0 ft below land surface.

Long-term water-level records for three observation wells completed in the Wind River Formation provide information on the water-level fluctuations in the wells and are based on measurements made in 1966 and 1967 and from 1970-83. Observation well 1S-3E-07dcd01, about 4 mi northwest of Arapahoe in the Little Wind River drainage area, is 130 ft deep. On the basis of 63 water-level measurements, water levels in this well ranged from 72.4 to 80.4 ft below land surface, with a mean value of 76.7 ft below land surface. Observation well 1S-3E-29ccc01, about 3 mi southwest of Arapahoe in the Popo Agie River drainage basin, is 210 ft deep. On the basis of 62 water-level measurements, water levels in this well ranged from 133.6 to 141.2 ft below land surface, with a mean value of 136.4 ft below land surface. Observation well 4N-1E-18dbc01, in the Fivemile Creek drainage basin, is 272 ft deep. On the basis of 61 water-level measurements, water levels in this well ranged from 92.8 to 110.9 ft below land surface, with a mean value of 101.3 ft below land surface.

Some deep wells completed in the Wind River Formation are flowing or are under confined conditions. Most of the 26 inventoried wells that flow or have been flowing, range from 225 to 450 ft deep and are located near Arapahoe and Riverton. Flow rates of 0.1, 2.5, and 5.0 gal/min were measured at three wells. Some of the 26 inventoried wells that were flowing in the 1950's and 1960's were not flowing from 1989 through 1991. Increased well drilling and pumping of wells near the flowing wells are probably major causes of the cessation of flow. Well-interference effects on flowing wells near Arapahoe were evaluated by Robinove (1958) on the basis of a pumping test performed in 1958 at a newly drilled, 450 ft deep, high-capacity (250 to 300 gal/min) industrial well about 2 mi southwest of Riverton. During the pumping test, the hydraulic heads in the four flowing wells completed in the same geologic unit declined below land surface or below the point of use. When pumping in the industrial well ceased, one well resumed flowing and hydraulic heads in the three other wells increased although the wells did not resume flowing (Robinove, 1958, p. 1).

Yields of water from the Wind River Formation vary greatly and are affected by the lithology of the formation. The water-yielding characteristics of wells completed in the Wind River Formation were evaluated from well-acceptance-test and pumping-test data that were collected during 1948-89. Yields for 266 wells ranged from 0.1 to 350 gal/min, with a median value of 20 gal/min. Specific-capacity determinations for 151 wells ranged from 0.04 to 23 (gal/min)/ft, with a median value of 0.4 (gal/min)/ft (table 5). Three pumping tests were conducted in 1958, 1965, and 1966, and the results are reported in McGreevy and others (1969, p I27-36). These pump tests had specific capacities of 1.5, 1.5, and 2.3 (gal/min)/ft. Specific capacity per foot of contribution for the Wind River Formation was estimated to have a probable range of 0.001 to 0.15 (gal/min)/ft per foot of contribution, with a mean value of 0.01 (gal/min)/ft per foot of contribution.

Mesozoic Rocks

The hydrologic characteristics of the following Mesozoic rocks were evaluated and summarized: Cody Shale, Frontier Formation, and Cloverly Formation of Cretaceous age; Nugget Sandstone of Jurassic (?) and Triassic (?) age; and Chugwater Group of Triassic age. Because of the lack of well and spring data, the hydrologic characteristics of the following rocks were not evaluated: Lance, Meeteetse, and Mesaverde Formations of Cretaceous age; Gypsum Spring and Sundance Formations of Jurassic age; and Dinwoody Formation of Triassic age. Physical and hydrologic characteristics of these other geologic units are described in McGreevy and others (1969, p. 115-18) and Richter (1981, p. 48-53).

Mesozoic rocks are exposed along the flanks of the Wind River Range and the Owl Creek Mountains and dip beneath the central part of the reservation (fig. 4). Many of these units also are exposed in numerous anticlinal structures on the reservation. These units usually contain highly fractured and deformed zones near outcrops.

Inventory records were compiled for 94 wells completed in and 8 springs flowing from Mesozoic geologic units on or near the reservation. Selected ground-water data for these inventoried wells and springs are listed in table 5. Most of the water-supply wells completed in these units are less than 150 ft deep and are located near the outcrops of these units.

Water in the Mesozoic rocks typically is confined, but water-level data were insufficient to evaluate the water-level conditions. These rocks are recharged primarily along outcrops by surface water and by infiltration of precipitation. Richter (1981, p. 91-93) used potentiometric indicators such as static water levels, altitudes of springs, and petroleum drill-stem tests to estimate that water movement in these units is generally toward the deepest part of the Wind River Basin, which is located below Boysen Reservoir.

Cody Shale

The Cody Shale consists of marine shale and sandstone and ranges in thickness from 3,000 to 4,500 ft. This geologic unit consists of an upper unit of interbedded sandstone and shale and a lower unit of shale. The sandstone is gray to tan, very fine to fine grained, thin bedded to platy, and calcareous. The shale is gray to black and commonly bentonitic and calcareous (Keefer, 1972, p. E15-16). Because of its marine depositional history, the Cody Shale probably contains substantial amounts of soluble minerals.

The Cody Shale easily weathers and erodes to form gentle slopes and flat areas. It is exposed on the sides of most anticlinal structures on the reservation. The Cody Shale also underlies Quaternary deposits in the Fort Washakie, Ethete, Ray Lake, Mill Creek, Boulder Flats, and Owl Creek areas.

Inventory records were compiled for 24 wells completed in the Cody Shale. Most of these wells are located in the Fort Washakie, Ray Lake, lower Mill Creek, and Owl Creek areas. Well depths range from 33 to 1,010 ft, with a median depth of 85 ft. Yields of water from wells completed in the Cody Shale were evaluated on the basis of nine yield measurements and six specific-capacity determinations from well-acceptance tests conducted during 1958-76. Yields ranged from 1.5 to 20 gal/min, with a median value of 5 gal/min. Specific capacities ranged from 0.03 to 1.4 (gal/min)/ft, with a median value of 0.4 (gal/min)/ft (table 5).

Frontier Formation

The Frontier Formation consists of alternating layers of sandstone and shale, and ranges in thickness from 500 to 1,000 ft. The sandstones are gray to brown, fine to medium grained, thin to thick bedded, and lenticular. The shales are gray to black, silty or sandy, and carbonaceous and are marine deposits (Keefer, 1972, p. E8 and E21). This geologic unit is exposed on the lower flanks of the Wind River Range, Owl Creek Mountains, and numerous anticlines.

Inventory records were compiled for 52 wells completed in and 2 springs flowing from the Frontier Formation. Selected ground-water data for these inventoried wells and springs are listed in table 5. Most of the wells completed in this formation are located in the Ethete, Fort Washakie, Ray Lake, lower Mill Creek, and Owl Creek areas. The two springs are located on the northern flanks of the Owl Creek Mountains. Well depths range from 31 to 3,760 ft, with a median depth of 94 ft. Yields of water from wells completed in this geologic unit were evaluated on the basis of 20 yield measurements and 11 specific-capacity determinations from wellacceptance tests conducted during 1957-90. Yields ranged from 0.5 to 40 gal/min, with a median value of 6.5 gal/min. Specific capacities ranged from 0.1 to 3.3 (gal/min)/ft, with a median value of 0.2 (gal/min)/ft. The two springs had flow rates of 0.6 and 1.2 gal/min (table 5).

Cloverly Formation

The Cloverly Formation consists of fine- to coarse-grained sandstone, shale, and thin lenticular pebble conglomerate and ranges in thickness from 200 to 300 ft. This formation consists of an upper sandstone unit, a middle shale unit, and a basal sandstone unit (Richter, 1981, p. 72). The Cloverly Formation is exposed on the flanks of the Wind River Range, Owl Creek Mountains, and anticlinal structures.

Inventory records were compiled for seven wells completed in and one spring flowing from the Cloverly Formation. Selected ground-water data for these inventoried wells and spring are listed in table 5. Most of these wells are located in the upper Trout Creek area near Fort Washakie. The spring is located on the northern flanks of the Owl Creek Mountains. Well depths range from 26 to 182 ft, with a median depth of 150 ft. Yields of water from wells completed in this geologic unit were evaluated on the basis of six yield measurements and four specific-capacity determinations from well-acceptance tests conducted during 1963-88. Yields ranged from 5 to 20 gal/min, with a median value of 13.5 gal/min. Specific capacities ranged from 0.3 to 4 (gal/min)/ft, with a median value of 2.7 (gal/min)/ft (table 5).

Nugget Sandstone

The Nugget Sandstone consists of fine- to medium-grained sandstone and ranges in thickness from 10 to 500 ft. This geologic unit is subdivided into an upper thin-bedded unit and a basal cross-stratified unit (Refolo, 1983, p. 21) and is exposed on the flanks of the Wind River Range.

Inventory records were compiled for five wells completed in the Nugget Sandstone. Selected ground-water data for these inventoried wells are listed in table 5. Most of these wells are located in the upper Trout Creek area near Fort Washakie. Well depths range from 40 to 7,240 ft, with a median depth of 63 ft. Yields of water from wells completed in this geologic unit were evaluated on the basis of four yield measurements and three specific-capacity determinations from well-acceptance tests conducted during 1980-90. Yields ranged from 10 to 90 gal/min, with a median value of 55 gal/min. Specific capacities ranged from 3.3 to 8.2 (gal/min)/ft, with a median value of 4.0 (gal/min)/ft (table 5).

Chugwater Group

The Chugwater Group consists of four major stratigraphic units. The upper unit, Popo Agie Formation, consists mostly of reddish siltstone, shale, and silty sandstone and ranges in thickness from 200 to 300 ft. The next lower unit, Crow Mountain Sandstone, consists of red to orange, fine- to coarse-grained sandstone and siltstone, and ranges in thickness from 10 to 90 ft. The next lower unit, Alcova Limestone, consists of very hard, finely crystalline limestone and ranges in thickness from 5 to 20 ft. The lowest unit, Red Peak Formation, consists of interbedded reddish siltstone, shale, mudstone, and fine-grained silty sandstone, and ranges in thickness from 700 to 1,000 ft (McGreevy and others, 1969, p. 118). The Chugwater Group is exposed on the flanks of the Wind River Range and Owl Creek Mountains and near the top of some anticlines.

Inventory records were compiled for six wells completed in and five springs flowing from the Chugwater Group. Selected ground-water data for these inventoried wells and springs are listed in table 5. Most of these wells and springs are located on the flanks of the Wind River Range and Owl Creek Mountains. Well depths range from 37 to 101 ft, with a median depth of 66 ft. Yields of water from wells completed in this geologic unit were evaluated on the basis of five yield measurements and four specific-capacity determinations from well-acceptance tests conducted during 1979-90. Yields ranged from 9 to 20 gal/min, with a median value of 18 gal/min. Specific capacities ranged from 1.0 to 4.5 (gal/min)/ft, with a median value of 1.2 (gal/min)/ft. Flow rates from four springs ranged from 2 to 75 gal/min, with a median value of 7 gal/min (table 5).

Paleozoic Rocks

The hydrologic characteristics of the following Paleozoic rocks were evaluated and summarized: Phosphoria Formation and related rocks of Permian age, Tensleep Sandstone of Pennsylvanian age, and Madison Limestone of Mississippian age. Because of the lack of well and spring data, the hydrologic characteristics of the following Paleozoic rocks were not evaluated: Amsden Formation of Pennsylvanian and Mississippian age, Darby Formation of Devonian age, Bighorn Dolomite of Ordovician age, and Gallatin

Limestone, Gros Ventre Formation, and Flathead Sandstone of Cambrian age. Physical and hydrologic characteristics of these other Paleozoic rocks are described in McGreevy and others (1969, p. 119-20). Paleozoic rocks are exposed along the upper flanks and the top of the Owl Creek Mountains and the upper flanks of the Wind River Range (fig. 4).

Inventory records were compiled for 19 wells completed in and 3 springs flowing from Paleozoic geologic units on the reservation. Selected ground-water data for these inventoried wells and springs are listed in table 5.

Water in the Paleozoic rocks typically is confined but water-level data were insufficient to evaluate the potentiometric water-level conditions. These rocks are recharged primarily along outcrops by surface water and by infiltration of precipitation. Richter (1981, p. 91-93) used potentiometric indicators such as static water levels, altitudes of springs, and petroleum drill-stem tests to estimate that water movement in these units is generally toward the deepest part of the Wind River Basin, which is located below Boysen Reservoir.

Yield data from water-supply wells were insufficient to evaluate and summarize the water-yield characteristics of some Paleozoic rocks. Some of the rocks, such as the Phosphoria Formation and related rocks, Tensleep Sandstone, and Madison Limestone, are major oil-and-gas production zones. Production and drillstem test data from oil-and-gas wells have been summarized by Richter (1981, p. 46-88) to estimate water-yield characteristics of some of these units.

Phosphoria Formation and related rocks

The Phosphoria Formation and related rocks consists mostly of interbedded limestone, chert, siltstone, very fine-grained sandstone, and thin deposits of shale and phosphate rocks (Keefer and Van Lieu, 1966, p. B44) and range in thickness from 150 to 300 ft. The Phosphoria Formation and related rocks are exposed on the east flanks of the Wind River Range and the north flanks of the Owl Creek Mountains. These rocks erode to form the prominent, grass-covered dip slopes called "flatirons" on the east flank of the Wind River Range. This unit is one of the most important oil-and-gas reservoirs on the reservation and many oil-and-gas wells are completed in this unit.

Inventory records were compiled for 13 wells completed in and 1 spring flowing from the Phosphoria Formation and related rocks. Selected ground-water data for these inventoried wells and spring are listed in table 5. Six of the inventoried wells are petroleum wells and are located in the northern part of the reservation. The other seven wells and one spring are located on the flanks of the Wind River Range, Owl Creek Mountains, and some anticlines. Well depths range from 200 to 6,750 ft., with a median depth of 1,720 ft.

Water yield data are limited for these rocks. A flow rate of 1 gal/min was measured from one flowing well and one spring. On the basis of selected oil-and-gas well data, Richter (1981, p. 70-71) estimated that this unit yields from 20 to 1,500 gal/min.

Tensleep Sandstone

The Tensleep Sandstone consists mostly of buff, tan, and white, fine-grained, massive to cross-bedded sandstone and ranges in thickness from 200 to 440 ft. This formation is exposed as conspicuous cliffs along the east flank of the Wind River Range and north flank of the Owl Creek Mountains.

Hydrologic information for the Tensleep Sandstone on the reservation is limited. The well and spring inventory for this geologic unit consists of three water-supply wells and one spring (table 5). On the basis of the physical characteristics of the unit and data from oil-and-gas wells in the Wind River Basin, the Tensleep Sandstone has the potential to yield substantial quantities of water. Richter (1981, p. 56-62) estimated that yields of water from wells completed in the Tensleep Sandstone could be as much as 2,000 gal/min. Most of the wells with yields greater than 500 gal/min have been completed in the upper 200 ft of this formation. McGreevy and others (1969, p. I18 and I39) estimated yields as much as 1,000 gal/min are possible from wells completed in the Tensleep Sandstone.

Ground-water data from three flowing wells completed in the Tensleep Formation on the east flank of the Wind River Range about 3 mi south of the reservation were evaluated. A yield of 75 gal/min was reported for a domestic water-supply well (33N-100W-18bdd01), 900 ft deep, southwest of Lander (Ralph Sjostrom, well owner, oral commun., 1990). A flow rate of 14 gal/min was measured from a 2-in. core test hole 450 ft deep (33N-100W-18cba01) completed in the upper 100 ft of the Tensleep Sandstone. A yield of 42 gal/min was measured from an irrigation well (33N-101W-13aba01), 700 ft deep.

The Tensleep Sandstone is probably the primary water source for the Washakie Mineral Hot Springs (Whitcomb and Lowry, 1968, p. 6), about 2.5 mi east of Fort Washakie. Flow rates of 150 gal/min from this spring were reported by Breckenridge and Hinckley (1978, p. 18). A flow rate of 332 gal/min from this spring was measured in October 1989.

The yields for water-supply wells completed in Paleozoic aquifers, which include the Tensleep Sandstone in the Ten Sleep area, southeastern Bighorn Basin, about 50 mi northeast of Thermopolis, were evaluated and summarized by Cooley (1986, p. 24). These aquifers are located on the southwestern flanks of the Bighorn Mountains and have hydrogeologic conditions similar to the east flank of the Wind River Range. Most wells completed in the Tensleep Formation in the Ten Sleep area are flowing wells, and flow rates generally are less than 50 gal/min; but some wells have flow rates greater than 100 gal/min.

Madison Limestone

The Madison Limestone consists of two stratigraphic members. The upper member is about 100 ft thick and consists of thin to massive, irregular bedded, gray to tan dolomite and limestone. The lower member is 500 to 600 ft thick and consists of mostly bluish-gray to gray, massive to thin-bedded crystalline limestone and dolomitic limestone (Keefer and Van Lieu, 1966, p. B30-31). The Madison Limestone crops out on the east flank of the Wind River Range and the north flank of the Owl Creek Mountains.

Hydrologic information for the Madison Limestone on the reservation is limited. The well and spring inventory consists of three water-supply wells and one spring (table 5). On the basis of physical properties and data from oil-and-gas wells completed in this formation, the Madison Limestone has the potential to yield substantial quantities of water. McGreevy and others (1969, p. I19 and I39) estimated yields of as much as 1,000 gal/min are possible from wells completed in the Madison Limestone.

Ground-water data collected from three wells completed in the Madison Limestone on or near the reservation were evaluated. Well 2N-1W-18ccc01 is an industrial water-supply well, 4,210 ft deep, and is completed in the Madison Limestone at the Winkleman Dome oil field, which is located on the reservation about 10 mi northwest of Fort Washakie. This well does not flow but when pumped produces about 700 gal/min (Roger Willenbrecht, Amoco Production Company, oral commun., 1990). Well 2S-2E-19ccc01 is an industrial water-supply well, 2,930 ft deep, and is located at the Lander Hudson oil field, which is located on the reservation about 4 mi northeast of Lander. This well flows at a rate of about 262 gal/min at a pressure of 50 to 100 lb/in ² (James Malone, Amoco Production Company, oral commun., 1990). Well 33N-101W-13aba02 is an irrigation well, 1,400 ft deep, and is located on the east flank of the Wind River Range about 3 mi south of the reservation. Flow rates for this flowing well were reported on the driller's record to be about 1,300 to 1,500 gal/min when this well was completed in July 1989. As of July 1990, this well was reported to have a flow rate of 900 gal/min (Ralph Sjostrom, well owner, oral commun., 1990).

Yields from water-supply wells completed in the Madison Limestone and Bighorn Dolomite in the Ten Sleep area were summarized by Cooley (1986, p. 24). Most wells completed in these two units are flowing wells with flow rates of about 50 to 2,000 gal/min.

Precambrian Rocks

Precambrian rocks are exposed on the top of the Owl Creek Mountains and the Wind River Range (fig. 4) and consists of igneous and metamorphic rocks. Hydrologic characteristics of these rocks are described in McGreevy and others (1969, p. I21). In general, Precambrian rocks yield very little water. In some areas in the mountains, intrusively weathered and fractured Precambrian rocks (usually less than 100 ft deep) can yield sufficient quantities of water for domestic or livestock use.

SURFACE-WATER RESOURCES

Surface-water resources on the reservation consist of streams, lakes, and reservoirs. These resources provide water for domestic, public-supply, irrigation, livestock, and industrial uses. These resources also provide recreational benefits and habitat for fish and other wildlife.

Streams

Streams are the major surface-water resource on the reservation. About 100 perennial streams, with a combined total length of about 1,100 mi, flow on the reservation. Numerous unnamed intermittent and ephemeral streams are present (Baldes, 1986a, p. 1-5).

Streams originating in mountain areas usually have perennial flow. The amount and timing of flow in these streams are controlled by climatic factors, and the physical characteristics and geologic material of the drainage basins. Important climatic factors include precipitation, temperature, wind, and evaporation. These factors are related to the altitude and physiographic features of the drainage basin. The most important physical characteristic is drainage-basin size (Peterson and others, 1987, p. 30). Flow in perennial streams is derived mostly from melting snowpack and usually is highest during peak snowmelt from May to July. Streamflow during the rest of the year is derived mostly from ground-water discharge from flood-plain alluvium. Some larger streams, such as Dinwoody Creek and Bull Lake Creek that flow from the east flank of the Wind River Range, derive part of their late-season (August to October) flows from glacial icemelt (Kerr and others, 1989, p. 18).

Most intermittent or ephemeral streams on the reservation originate in the foothills or plains in the central and eastern parts of the Wind River Basin. An intermittent stream is a stream or reach of a stream that flows at certain times of the year when it receives water from a spring or from a surface source such as melting snow. An ephemeral stream is a stream or reach of a stream that flows briefly only in direct response to precipitation and whose channel is at all times above the water table (Langbein and Iseri, 1960, p. 18). The amount and timing of flow in these streams are controlled mostly by the quantity and intensity of precipitation, drainage-basin size, evapotranspiration, and permeability of the surficial material. Rainfalls or snowmelt that exceed the infiltration rate of the surficial material produce streamflow in these streams.

The Wind River is the main river draining the reservation and the entire Wind River drainage basin. The Wind River originates in the Absaroka Range and flows in a southeasterly direction for about 114 mi to its junction with the Little Wind River near Riverton (Bureau of Reclamation, 1981, p. 11). The Wind River then turns north and flows into Boysen Reservoir and through the Wind River Canyon. Downstream from the outlet of the Wind River Canyon, the river is called the Bighorn River (pl. 4). Major tributaries to the Wind River flowing through the reservation (in downstream order), include East Fork Wind River (which forms part of the western boundary of the reservation), Dinwoody Creek, Dry Creek, Crow Creek, Meadow Creek, Willow Creek, Bull Lake Creek, Little Wind River, Popo Agie River (which forms part of the southern boundary of the reservation), Beaver Creek, Fivemile Creek, and Muddy Creek (pl. 4).

The northern part of the reservation, which is in the Owl Creek drainage basin, is drained by South Fork Owl Creek and Owl Creek. These two perennial streams originate in the Absaroka Range and form part of the northern boundary of the reservation (pl. 4). Owl Creek is a tributary of the Bighorn River downstream from the reservation.

Streamflows of many larger streams on the reservation are affected and regulated by irrigation diversions and storage structures. There are many diversions from the Wind River; the largest diversion is the Wyoming Canal. The Wyoming Canal is the principal source of irrigation water for the Riverton Reclamation Withdrawal Area. Other major irrigation diversions from the Wind River include the Johnstown Canal, LeClair Canal, Left Hand Canal, and Wyoming Central Canal (pl. 4). The Washakie Reservoir dam is on the South Fork Little Wind River and controls flow in this river. Flow in the North Fork Little Wind River is affected by a canal diversion that transfers water into the South Fork Little Wind River. The dam at the outlet of Bull Lake controls flow in Bull Lake Creek and also has a major effect on regulating flow in the Wind River. A small dam and canal diversion at the outlet of Dinwoody Lakes have a major effect on the flow in Dinwoody Creek. Flow in lower reaches of Dry, Meadow, and Willow Creeks, which are on the east flank of the Wind River Range, are affected by a canal system that crosses and diverts some water from these streams. Flow in lower reaches of the South Fork Owl Creek is affected by the Anchor Reservoir dam, which is on this stream.

Streams with Streamflow-Gaging Stations

Sixty active or inactive USGS streamflow-gaging stations are located on or near (within 2 mi.) the reservation (pl. 4). The type and period of discharge record and availability of water-quality data for these 60 gaging stations are listed in table 6. Gaging stations in the Riverton Reclamation Withdrawal Area are not included in table 6. Detailed information about the location, discharge records, and water-quality records of gaging stations on the Riverton Reclamation Withdrawal Area and other sites outside of the reservation are listed in a report by Ruby and others (1991). The period of record and number of water-quality analyses at 33 gaging stations with water-quality data are listed in table 17 in a subsequent section of the report.

Discharge records are of two types: monthly or daily discharges, and annual peak discharge only. Streamflow-gaging stations with monthly or daily discharge records are considered continuous-record stations when discharge or stage is measured daily, weekly, or monthly for a continuous period. These gaging stations generally are located on perennial streams and commonly have a shelter that houses a data recorder and stage (water levels) sensing equipment. For most of these gaging stations, the daily mean streamflow is calculated on the basis of continuous stage records and periodic measurements of instantaneous streamflow. Some of the newer streamflow-gaging stations on the reservation are equipped with data-collection platforms, which allow stage data to be transmitted by satellite to off-site locations so that streamflow conditions can be monitored frequently. Gaging stations with annual peak-discharge records only are located primarily on ephemeral or intermittent streams and measure only peak flows. Druse and others (1988) contains additional information and the annual maximum-discharge data for the gaging stations with annual peak-discharge records listed in table 6.

Miscellaneous Surface-Water Sites

Surface-water discharge has been measured or water-quality samples have been collected occasionally at 39 miscellaneous surface-water sites on the reservation (pl. 4). These miscellaneous surface-water sites are located on streams, irrigation canals, and irrigation drains. The year and type of record for discharge and water-quality analyses for miscellaneous surface-water sites are listed in table 7. Miscellaneous surface-water sites have two types of discharge records: seasonal and miscellaneous. Sixteen miscellaneous surface-water sites have seasonal discharge measurements and are located primarily on canals or streams near diversion structures. Cantilever gages were installed at these sites to determine stage for which discharge is estimated throughout the irrigation season. Twenty-three sites have miscellaneous surface-water discharge measurements, which were made when water-quality samples were collected.

Table 6. Type and period of record for discharge measurements, and availability of water-quality data for selected streamflow-gaging stations on or near the Wind Reservation, Wyoming, through 1990

[Site number: site number used in this report. Streamflow-gaging station number: see text for description of streamflow-gaging station numbering system. Asterisk (*) preceding the streamflow-gaging station number indicates the stream site has 10 years or more of daily discharge records. Annual peak discharge: peak flow data only. Abbreviations: deg, degrees; min, minutes, sec, seconds; mi², square miles; --, no data]

	Streamflow-		Location (deg, min, sec)	eg, min, sec)		Period of record	Period of record by calendar year	
Site number (plate 4)	gaging station number	Streamflow-gaging station	Latitude	Longitude	Drainage area (mi²)	Monthly or daily discharge	Annual peak	Water- quality data ²
GI	* 06220500	East Fork Wind River near Dubois	432716	1092757	427	1950-57, 1975-		yes
G2	06220800	Wind River above Red Creek, near Dubois	432549	1092641	;	;	ł	yes
G3	06221400	Dinwoody Creek above lakes, near Burris	432044	1092434	88.2	1957-78, 1988-	i	yes
G4	* 06221500	Dinwoody Creek near Burris	432555	1092101	100	1909, 1918-30, 1950-58	i	no
GS	06222000	Wind River near Burris	432550	1092045	1,236	1946-53	i	ou
95	* 06222500	Dry Creek near Burris	432010	1091820	357	1909, 1921-40, 1988-	ľ	yes
C2	06222510	Dry Creek Canal at headgate, near Burris	432038	1091725	ŀ	1989-	1	ou
85	* 06222700	Crow Creek near Tipperary	433437	1091542	30.2	1962-	;	yes
6 9	06223000	Meadow Creek near Lenore	431740	1091255	41.7	1909, 1921-23	1	ou
G10	* 06223500	Willow Creek near Crowheart	431658	1091102	55.3	1909, 1921-23, 1925-40, 1988-	1	yes
G11	06223700	Sand Draw near Crowheart	431550	1090505	12.8	1	1961-77	no
G12	06223800	Wind River tributary number 2 near Crowheart	431418	1090152	3.16	ŀ	1961-81	no
G13	* 06224000	Bull Lake Creek above Bull Lake	431037	1091208	187	1941-53, 1966-	ł	yes
G14	06224500	Bull Lake Reservoir near Lenore	431235	1090230	210	1938-	1	ou
G15	* 06225000	Bull Lake Creek near Lenore	431433	1090120	213	1918-	i	yes
G16	* 06225500	Wind River near Crowheart	431433	1090035	1,891	1945-	1	yes
G17	06226000	Wyoming Canal near Lenore	431345	1085340	1	1941-45, 1949-82, 1988-	ł	yes
G18	06226200	Little Dry Creek near Crowheart	433210	1090520	10.5	;	1961-81	ou
G19	06226300	Dry Creek near Crowheart	432340	1090225	6.76	ŀ	1959, 1961-81	ou
G20	06227600	Wind River near Kinnear	430834	1084232	2,194	1974-79	ŀ	yes
G21	06227700	LeClair Canal near Riverton	430229	1082546	1	1989-	;	yes

 Table 6. Type and period of record for discharge measurements, and availability of water-quality data for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990--Continued

	Streamflow-		Location (deg, min, sec)	g, min, sec)		Period of record ¹ by calendar year	by calendar year	7,7
Site number (plate 4)	gaging station	Streamflow-gaging station	Latitude	Lonaitude	Drainage area (mi²)	Monthly or daily discharge	Annual peak discharge	water- quality data ²
G22	* 06228000	Wind River at Riverton	430038	1082232	2,309	1906-08, 1911-		yes
G23	* 06228350	South Fork Little Wind River above Washakie Reservoir, near Fort Washakie	425806	1090213	90.3	1976-	ŀ	yes
G24	06228450	South Fork Little Wind River below Washakie Reservoir	425904	1085957	93.5	1988-	•	yes
G25	* 06228500	Little Wind River near Fort Washakie	430000	1085605	117	1921-40	ŀ	ou
G26	06228510	Ray Canal at headworks, near Fort Washakie	430002	1085556	ł	-6861	;	ou
G27	06228800	North Fork Little Wind River near Fort Washakie	430138	1090002	112	1988-	1	yes
G28	* 06229000	North Fork Little Wind River at Fort Washakie	430040	1085310	128	1921-40	ŀ	ou
G29	06229680	Sage Creek above Norkok Meadows Creek, near Fort Washakie	430456	1085334	118	1990-	1	yes
G30	06229700	Norkok Meadows Creek near Fort Washakie	430456	1085412	15.4	!	1965-81	ou
G31	06229800	Sand Draw near Fort Washakie	430342	1085444	66.	;	1961-81	ou
G32	06229900	Trout Creek near Fort Washakie	425704	1085654	16.1	1990-	1961-68, 1970-84	yes
G33	06230190	Mill Creek above Ray Lake outlet, near Fort Washakie	425650	1084829	15.8	1990-	ł	yes
G34	06230300	Ray Lake outlet near Fort Washakie	425713	1084847	1	!	ł	yes
G35	06230500	Little Wind River near Arapahoe	425858	1083554	618	1950-53	1	ou
G36	* 06231000	Little Wind River above Arapahoe	425737	1082954	099	1906-09, 1911-18, 1979-	ì	yes
G37	* 06232000	North Popo Agie River near Milford	425150	1085425	98.4	1945-63	!	ОП
G38	* 06232500	North Popo Agie River near Lander	425259	1084716	134	1938-53	1	ou
G39	06232600	Popo Agie River at Hudson Siding, near Lander	425159	1084104	1	;	;	yes
G40	* 06233500	Little Popo Agie River at Hudson	425404	1083512	384	1907-09, 1911-17 1938-53	ł	ou
G41	06233600	Popo Agie River at Hudson	425445	1083407	ł	1	ł	yes
G42	* 06233900	Popo Agie River near Arapahoe	425647	1083034	962	1979-	1	yes
G43	06234000	Little Wind River below Arapahoe	425720	1082915	1,464	1906-09, 1911-18	1	ou

Table 6. Type and period of record for discharge measurements, and availability of water-quality data for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990--Continued

	Streamflow-		Location (deg, min, sec)	g, min, sec)		Period of record ¹ by calendar year	by calendar year	
Site number	gaging station				Drainage	Monthly or daily	Annual peak	Water- quality
(plate 4)	number	Streamflow-gaging station	Latitude	Longitude	area (mi²)	discharge	discharge	data ²
G44	06235000	Beaver Creek near Arapahoe	425716	1082539	354	1950-53		yes
G45	* 06235500	Little Wind River near Riverton	425951	1082229	1,904	1941-	;	yes
G46	06235700	Haymaker Creek near Riverton	430454	1082246	9.52	1	1961-64, 1966-73	no
G47	06236000	Kirby Draw near Riverton	430529	1081606	129	1951-53	1961-84	ou
G48	06236100	Wind River above Boysen Reservoir, near Shoshoni	430743	1081328	4,390	1990-	i	yes
G49	* 06239000	Muskrat Creek near Shoshoni	430853	1080927	733	1950-73	i	yes
G50	* 06244500	Fivemile Creek above Wyoming Canal, near Pavillion	431805	1084208	118	1949-75, 1988-	1	yes
G51	06257300	Shotgun Creek tributary near Pavillion	432735	1084437	2.57	1	1961-81	no
G52	* 06257500	Muddy Creek near Pavillion	432146	1083608	267	1949-73	ł	yes
G53	* 06259000	Wind River below Boysen Reservoir	432530	1081042	7,701	1951-	;	yes
G54	* 06260000	South Fork Owl Creek near Anchor	433953	1085202	85.5	1932, 1939-43, 1959-85	I	yes
G55	06260200	Middle Fork Owl Creek above Anchor Reservoir	434000	1085200	33.6	1959-65	ł	ОП
G56	06260300	Anchor Reservoir	433950	1084927	131	1960-	1	no
G57	* 06260400	South Fork Owl Creek below Anchor Reservoir	433957	1084734	131	1959-	:	по
G58	06260500	South Fork Owl Creek above Curtis Ranch	434100	1084400	144	1943-59	1	yes
G59	06261000	South Fork Owl Creek at Curtis Ranch	434300	1084200	149	1931-32, 1938-43	I	no
G60	06261500	South Fork Owl Creek near Thermopolis	434300	1083800	180	1921-22, 1929-32	1	no

¹Period of record includes partial years of record.

²Type, period of record, number of water-quality analyses for streamflow-gaging stations with water-quality data are listed in table 17 of this report. ³Approximate value.

Table 7. Type of record for discharge measurements and water-quality analyses for miscellaneous surface-water sites on or near the Wind River Indian Reservation, Wyoming, through 1990

[Site number: site number used in this report. Miscellaneous surface-water site number: see report text for description of this site-numbering system. Abbreviations: deg, degrees, min, minutes; sec, seconds. Discharge type: m, miscellaneous measurement; s, seasonal measurement. Water-quality type: w, water-quality properties (specific conductance, pH, temperature, or turbidity); n, nutrient and major constituent data; t, trace element data; r, radiochemical data; p, pesticide data; --, no data]

	:						
Site	Miscellaneous surface-water site						or water- quality
(plate 4)	number	Miscellaneous surface-water site	Latitude	Longitude	Discharge	Water quality	analyses
M I	425135108425401	North Fork Popo Agie River near confluence Middle Fork Popo Agie River, near Lander	425135	1084254	1990 m	1990 w,n	1
M2	425259108523401	Surrell Creek near Milford	425259	1085234	1990 m	1990 w	-
M3	425348108351301	Little Popo Agie River near Hudson	425348	1083513	1990 m	1990 w,n	
M4	425513108485801	Ray Canal below 65-C lateral, near Milford	425513	1084858	1989 s	;	:
MS	425515108485401	65-C lateral at headworks	425515	1084854	1989 s	;	;
M6	425605108515401	Mill Creek above Ray Canal, near Wind River	425605	1085154	1990 ш	1990 w,n,t	2
M7	425709108521201	Ray Canal at siphon, near Wind River	425709	1085212	1989 s	1	1
M8	425710108460701	Mill Creek below Coolidge Canal, near Wind River	425710	1084607	1989 s	1990 w,n,t	_
M9	425713108485601	Ray Lake outlet near Wind River	425713	1084856	1989 s	1990 w,n,t	-
M10	425716108520401	37-C lateral at headworks, near Wind River	425716	1085204	1989 s	1990 w,n,t	1
M11	425730108461201	McCaskey Drain above Coolidge Canal, near Wind River	425730	1084612	1990 m	1990 w,n,t	-
M12	425829108521801	Alkali Lake outlet above Trout Creek 'B' Canal, near Wind River	425829	1085218	1990 m	1990 w,n,t	-
M13	425850108550701	Trout Creek below Ray Canal, near Wind River	425850	1085507	s 6861	1990 w	_
M14	425857108352101	Sub-Agency Ditch at auxiliary gage, near Arapahoe	425857	1083521	1989 s	ŀ	:
M15	425901108372101	Sharp Nose Drain above Little Wind River, near Arapahoe	425901	1083721	1990 m	1990 w,n,t	_
M16	425923108245301	Drain below ore pile, Wind River Indian Reservation	425923	1082453	1985 m	1985 r	_
M17	425958108403501	Mill Creek above Little Wind River, near Ethete	425958	1084035	1990 m	1990 w,n,t	_
M18	430015108403601	Lower Hansen Drain above Little Wind River, near Ethete	430015	1084036	1990 m	1990 w,n,t,p	
M19	430036108525801	South Fork Little Wind River at Fort Washakie	430036	1085258	1990 m	1990 w,n	_
M20	430040108525901	North Fork Little Wind River at Fort Washakie	430040	1085259	1990 m	1990 w,n	_
M21	430045108480001	Coolidge Canal below Trout Creek, near Ethete	430045	1084800	1989 s	1990 w,n,t	1
M22	430114108431001	Ethete Drain above Little Wind River, near Ethete	430114	1084310	1990 m	1990 w,n,t	_

Table 7. Type of record for discharge measurements and water-quality analyses for miscellaneous surface-water sites on or near the Wind River Indian Reservation, Wyoming, through 1990--Continued

			Location (deg, min, sec)	g, min, sec)	Year and ty	Year and type of record	Number
Site number (plate 4)	Miscellaneous surface-water site	Miscellaneous surface-water site	atiti do	Conditude	Discharge	Water quality	of water- quality
M23	430129108480101	Little Wind River at water-supply plant, near Ethete	430129	1084801	1990 m	1990 w.n	1
707	420124108211301	I oft Hand Court of headersale, more Director	430134	1002113	1080		ı
M24	430134108311201	Lett Hand Canal at neadworks, near Kiverton	450134	1083112	1989 S	:	;
M25	430902108434101	Johnstown Canal at headworks, near Kinnear	430902	1084341	s 6861	ł	ŀ
M26	431707109105201	Willow Creek Canal at headworks, near Crowheart	431707	1091052	1989 s	i	;
M27	431744109123001	Meadow Creek Canal at headworks, near Crowheart	431744	1091230	1989 s	;	:
M28	431757109082601	Willow Creek near confluence Wind River, near Crowheart	431757	1090826	1990 ш	1990 w,n	-
M29	431950109085501	Crow Creek near confluence Wind River, near Lenore	431950	1090855	1990 m	1990 w,n	
M30	432208109151401	Lower Wind River "A" canal at headworks, near Burris	432208	1091514	1989 s	ı	;
M31	432302109215601	Dinwoody Canal at headworks, near Wilderness	432302	1092156	s 6861	ł	1
M32	432430109252001	Red Creek near confluence Wind River, near Wilderness	432430	1092520	1990 m	1990 w,n	
M33	432609109205001	Upper Wind River above canal, at headworks	432609	1092050	1989 s	ŀ	1
M34	433027109092701	Red Creek above Maverick Springs Road, near Lenore	433027	1090927	1990 m	u 0661	—
M35	433155109054301	Dry Creek above Maverick Springs Road, near Lenore	433155	1090543	1990 m	1990 w,n	
M36	434035109062101	South Fork Owl Creek above Rock Creek, near Anchor Reservoir	434035	1090621	1990 m	1990 w,n	-
M37	434326108320201	Owl Creek near Hamilton Dome	434326	1083202	1990 m	1990 w,n,t	
M38	434204108472901	North Fork Owl Creek near Anchor Reservoir	434204	1084729	1990 m	1990 w,n,t	-
M39	434331108321601	Owl Creek at Arapahoe Ranch, near Thermopolis	434331	1083216	1989 m	1990 w,n	-

Flow Characteristics of Streams with Streamflow-gaging Stations

Streamflow data from 24 streamflow-gaging stations with 10 years or more of daily discharge (flow) records were evaluated and summarized to provide a representative, long-term overview of the streamflow characteristics of rivers and streams on the reservation. The selected 24 gaging stations are designated in table 6 with an asterisk "*" preceding the gaging-station number. Statistical summaries of streamflow data were determined at each selected gaging station and listed in tabular format in appendix 1 at the end of the report. The following statistical summaries were determined for each gaging station: (1) summary of monthly and annual discharge, (2) magnitude and frequency of annual low flow, (3) magnitude and frequency of instantaneous peak flow, (4) magnitude and frequency of annual high flow, and (5) duration table of daily mean flow. All the data and procedures used to produce these summaries were generated by the Water Data Storage and Retrieval System (WATSTORE) data base (U.S. Geological Survey, 1975). The period of record and discharge data used in these statistical summaries were based on water years and consist of discharge data through water year 1989, where available.

The maximum, minimum, mean, standard deviation, coefficient of variation, and percentage of annual runoff by month and annual total for mean monthly and annual discharges are listed in the first statistical summary table (appendix 1). Data from this summary table can be used to estimate when the highest and lowest mean monthly discharges might occur. Using East Fork Wind River near Dubois (site G1) as an example, the largest mean monthly discharge can be expected in June (1,050 ft ³/s) and the smallest mean monthly discharge in February (47 ft ³/s).

The magnitude and frequency of annual low flows are listed in the second statistical summary table (appendix 1). Low flows were calculated for the 1-, 3-, 7-, 14-, 30-, 60-, 90-, 120-, and 183-day periods. For each low-flow period the mean discharge was calculated for the 2-, 5-, 10-, 20-, 50-, and 100-year recurrence interval or 50, 20, 10, 5, 2, and 1 percent nonexceedance probabilities. Recurrence interval is the long-term average number of years between occurrences, but it implies no regularity of occurrence. For example, a 50-year low-flow event might occur in consecutive years, or it might not occur in a 100-year period. The nonexceedance probability is the reciprocal of the recurrence intervals and is the chance that a low-flow event will not be exceeded in any 1 year. Data from this summary table can be used to evaluate the expected low flows for a given time period. Using East Fork Wind River near Dubois (site G1) as an example, there is a 5-percent chance (recurrence interval of 20 years) that a mean 7-day flow of about 21 ft ³/s or less will occur in any 1 year.

The magnitude and frequency of instantaneous peak flows are listed in the third statistical summary table (appendix 1). Instantaneous peak flows were calculated for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals or 50, 20, 10, 4, 2, and 1 percent exceedance probabilities. The data used in this table are instantaneous discharges rather than daily mean discharge data used in the other tables. Data from this summary table can be used to estimate the expected peak flow for a given recurrence interval or exceedance probability. Using East Fork Wind River near Dubois (site G1) as an example, there is a 2-percent chance (recurrence interval of 50 years) that an instantaneous peak flow of about 7,530 ft 3 /s or greater will occur in any 1 year.

The magnitude and frequency of annual high flows are listed in the fourth statistical summary table (appendix 1). High flows were calculated for the 1-, 3-, 7-, 15-, 30-, 60-, and 90-day periods. For each high-flow period, the mean discharge was calculated for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval or 50, 20, 10, 4, 2, and 1 percent exceedance probabilities. Data from this summary table can be used to evaluate the expected high-flow discharge for a given time period. Using East Fork Wind River near Dubois (site G1) as an example, there is a 4-percent chance (recurrence interval of 25 years) that a mean 7-day high flow of about 3,230 ft ³/s or more will occur in any 1 year.

The duration table of daily mean flow for all complete water years of record is listed in the fifth statistical summary table (appendix 1). This flow-duration table contains the percentage of time that a given daily mean discharge was equalled or exceeded. Discharges were calculated for the 1, 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 95, 98, 99, 99,5, and 99,9 percentiles. Data from this table can be used to evaluate the flow characteristics of past discharge records at a streamflow-gaging station. Using East Fork Wind River near Dubois (site G1) as an example, daily mean flows of 40 ft³/s were exceeded 90 percent of the days for the period of record, and daily mean flows of 1,100 ft³/s were exceeded 5 percent of the days for the period of record.

Evaluation of the streamflow statistical summaries indicate some general flow characteristics for streams with streamflow-gaging stations. Twenty-one of the 24 gaging stations with 10 years or more of daily discharge records are on perennial streams. The three gaging stations located on intermittent streams are described in the next paragraph. Eighteen of the 21 gaging stations on perennial streams had their largest mean monthly discharge in June, which ranged from 25.9 to 42.1 percent of the mean annual discharge, with an average value of 35.5 percent (appendix 1). Except for North Popo Agie River near Milford (site G37), the smallest mean monthly discharge is in January or February for the 18 stations and ranged from 0.2 to 3.3 percent of the mean annual discharge, with an average value of 1.8 percent. Three gaging stations--Dinwoody Creek near Burris (site G4), Bull Lake Creek near Lenore (site G15), and Wind River below Boysen Reservoir (site G53) are located on perennial streams and had the largest mean monthly discharge for July. These three gaging stations are located downstream of major lakes or reservoirs. The mean monthly discharges at East Fork Wind River near Dubois (site G1) are shown in figure 5 and are representative of the monthly-flow distribution for perennial streams on the reservation.

Three of the 24 streamflow-gaging stations with 10 years or more of daily discharge records are located on intermittent streams. These three gaging stations are Muskrat Creek near Shoshone (site G49), Fivemile Creek above Wyoming Canal, near Pavillion (site G50), and Muddy Creek near Pavillion (site G52). The mean monthly discharges at these gaging stations were highly variable throughout the year as shown in figure 5 for site G50.

Average annual runoff, in acre-ft/mi² (acre-foot per square mile) was calculated for all 24 streamflowgaging stations. For the 21 gaging stations located on perennial streams, average annual runoff ranged from 122 acre-ft/mi² at South Fork Owl Creek below Anchor Reservoir (site G57) to 1,150 acre-ft/mi² at Bull Lake Creek above Bull Lake (site G13). Average annual runoff at the three gaging stations on intermittent streams ranged from about 3.5 to 14 acre-ft/mi².

Average annual runoff, for selected streamflow-gaging stations on the three major rivers on the reservation were as follows:

Wind River near Crowheart (site G16)	883,000 acre-ft/yr
Wind River at Riverton (site G22)	612,000 acre-ft/yr
Little Wind River above Arapahoe (site G36)	251,000 acre-ft/yr
Popo Agie River near Arapahoe (site G42)	180,000 acre-ft/yr
Little Wind River near Riverton (site G45)	419,000 acre-ft/yr
Wind River below Boysen Reservoir (site G53)	1,030,000 acre-ft/yr

The shape of a flow-duration curve can be used to evaluate the general flow characteristics at streamflowgaging stations. Generally, a steep flow-duration curve indicates highly variable flow conditions, and a gently sloping flow-duration curve indicates relatively uniform flow conditions. Perennial streams tend to have flowduration curves that are gently sloping at the lower end of the curve, indicating stable base flows. Intermittent and ephemeral streams generally have steeply sloping flow-duration curves at the lower end of the curve. Curves for intermittent and ephemeral streams frequently reach zero flow, which means there is no base flow. The shape of a flow-duration curve also is affected by irrigation and reservoir operations. Additional information on how flow-duration curves are calculated and used to evaluate the flow characteristics at a gaging station is described in Searcy (1959).

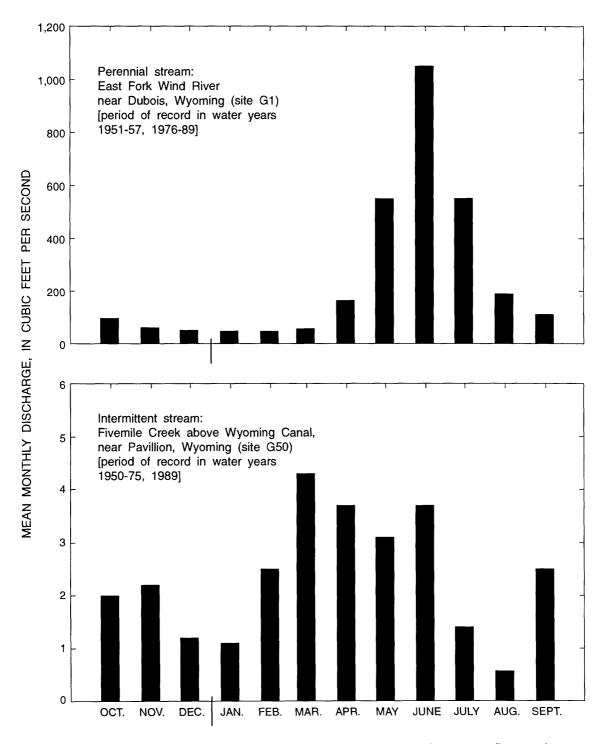


Figure 5. Mean monthly discharges at representative streamflow-gaging stations on a perennial stream and an intermittent stream, Wind River Indian Reservation, Wyoming.

For most of the streamflow-gaging stations on unregulated streams or streams with minor irrigation diversions, the flow-duration curves had similar shapes; the lower ends of the curves were gently sloping, indicating stable base-flow conditions as shown in figure 6 for East Fork Wind River near Dubois (site G1). For the gaging stations on the more regulated streams, which includes Dinwoody Creek near Burris (site G4), Bull Lake Creek near Lenore (site G15), Wind River at Riverton (site G22), Little Popo Agie River at Hudson (site G40), and Middle Fork Owl Creek above Anchor Reservoir (site G55), the shape of the flow-duration curves had a greater variation; the lower end of the curves tended to have steeper slopes indicating little or no base flow, as shown in figure 6 for site G15.

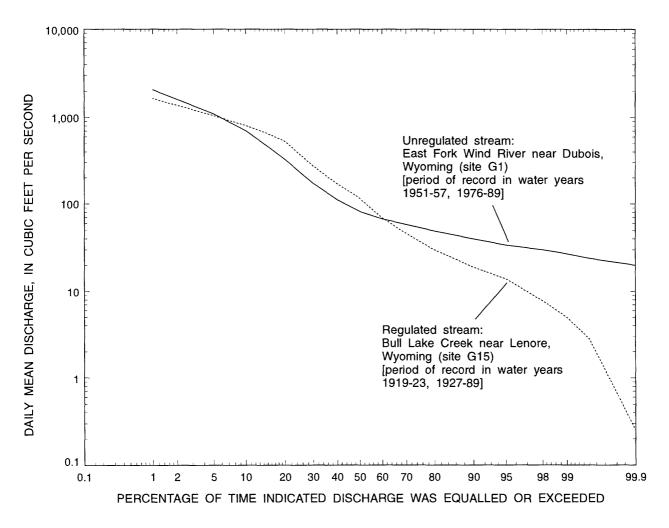


Figure 6. Flow-duration curves for representative streamflow-gaging stations on an unregulated stream and a regulated stream, Wind River Indian Reservatin, Wyoming.

Flow Characteristics of Streams without Streamflow-gaging Stations

Evaluation of the surface-water resources on the reservation also requires knowledge of flow characteristics for streams without streamflow-gaging stations (ungaged streams). Two methods developed by Lowham (1988) to estimate streamflow characteristics for ungaged streams in Wyoming were chosen to estimate the mean annual discharge at seven miscellaneous surface-water sites (M2, M3, M6, M20, M29, M34, and M35) on ungaged streams on the reservation (table 8). Mean annual discharge also was estimated for two gaging stations. Willow Creek near Crowheart (site G10) was re-established in 1989 after being discontinued in 1940. Sage Creek above Norkok Meadows Creek, near Fort Washakie (site G29) was established in 1990.

The first method to determine flow characteristics for ungaged streams uses regression equations developed between measured channel geometry (bankfull channel width) and the known mean annual discharge at sites with streamflow-gaging stations. The second method uses regression equations developed between basin characteristics (drainage area and mean annual precipitation) of basins with gaging stations and the known mean annual discharge for sites with gaging stations. Measured channel geometry and basin characteristics at ungaged sites can be used in these regression equations to estimate mean annual discharge for ungaged sites. Separate regression equations were developed for two different regions in Wyoming: Mountainous, and High Desert and Plains. The equations listed below (from Lowham, 1988, p. 28, 29, and 34) were used to estimate mean annual discharge by both methods for seven ungaged sites and two gaging stations (table 8).

Mountainous Regions:

$$Q = 0.087 WIDTH^{1.79}$$
 (Bankfull channel-width method) (1)

$$Q = 0.013 A^{0.93} PR^{1.43}$$
 (Area-precipitation method) (2)

High Desert and Plains Regions:

$$Q = 0.00046 WIDTH^{2.42}$$
 (Bankfull channel-width method) (3)

$$Q = 0.0021 A^{0.88} PR^{1.19}, \text{ (Area-precipitation method)}$$

where Q is the estimated mean annual discharge, in cubic feet per second; WIDTH is the bankfull channel width, in feet;
A is the contributing drainage area, in square miles; and PR is the average annual precipitation, in inches.

Lakes and Reservoirs

Lakes and reservoirs are important surface-water resources on the reservation and are described in Baldes (1981, 1986a). These water resources include high mountain lakes, and lowland lakes and reservoirs. The reservation has more than 220 high mountain lakes with a total surface area of about 4,450 acres. Most of these lakes are less than 15 acres in size and have surface altitudes of 9,000 ft or more above sea level. The name of the lake, major drainage basin in which the lake is located, and surface area in acres for all these lakes are listed in Baldes (1981, p. 10-21). All the high mountain lakes are located in the Wind River Range. The lowland lakes and reservoirs are on the lower flanks of the mountains or in the central part of the reservation and consist of numerous farm and stock ponds, natural lakes, two large (greater than 300 acres) irrigation-supply reservoirs, and numerous small (less than 20 acres) irrigation-supply reservoirs (Baldes, 1986b, p. 3-20). The major lowland lakes and reservoir are Dinwoody Lakes, upper Dinwoody Lake, Ray Lake, Bull Lake, and Washakie Reservoir.

[Site number: site number used in this report. Abbreviations: mi², square miles; ft, feet; ft³/s, cubic feet per second; in., inches. Drainage basin type: M, Mountainous region; HDP, High Desert Table 8. Flow characteristics for selected streams without or recent streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming and Plains region]

		ā	Drainage basin	sin	Bankfull	Estimated mean annual discharge, bankfull	Estimated mean	Estimated mean annual discharge, area-
Site number (plate 4)	Site name	Total area (mi²)	Туре	Area percentage by type	channel- width (ft)	channel-width method (ft³/s)	annual precipitation (in.)	precipitation method (ft³/s)
		Streams with	out streamf	Streams without streamflow-gaging stations	Suo			
M2	Surrell Creek near Milford	11.1	Σ	100	4.5	1.3	12	4.3
M3	Little Popo Agie River near Hudson	384	M HDP	39 61	39.0	25.9	12	49.4
M6	Mill Creek above Ray Canal, near Wind River	10.4	M HDP	34 66	3.3	હ	12	1.6
M20	North Fork Little Wind River at Fort Washakie	128	M HDP	84 16	50.0	81.3	22	83.7
M29	Crow Creek near confluence Wind River, near Lenore	79.5	M HDP	49	19.5	0.6	12	14.0
M34	Red Creek above Maverick Springs Road, near Lenore	15.0	HDP	100	11.4	2 ;	17	7.
M35	Dry Creek above Maverick Springs Road, near Lenore	24.4	HDP	100	13.8	κ;	17	1.0
	Streams	with recent (1	989 or 1990	Streams with recent (1989 or 1990) streamflow-gaging stations	ging stations			
G10	Willow Creek near Crowheart (gaging station re-established in 1989)	55.3	M HDP	76 24	16.6	10.2	15	20.3
G29	Sage Creek above Norkok Meadows Creek, near Fort Washakie (gaging station established in 1990)	118	M HDP	37 63	11.3	2.6		14.1

WATER QUALITY

Water quality is determined primarily by the concentration of inorganic and organic material dissolved and suspended in the water and by the physical properties of the water. Water quality is divided into three general categories--biological, physical, and chemical.

The biological quality of water consists primarily of plant and animal organisms living in water. A limited amount of biological data has been collected at surface-water sites on the reservation. These data include mostly microbiological analyses associated with fecal coliform and fecal streptococcal bacteria. The period of record and number of bacteria analyses of samples collected at streamflow-gaging stations are summarized later in this report (table 17), but biological-quality data were not evaluated in this report.

A major component of the physical quality of water is the concentration of suspended sediment in the water. A substantial number of suspended-sediment samples has been collected at selected streamflow-gaging stations on or near the reservation. The period of record and number of suspended-sediment samples analyzed for these gaging stations are summarized later in this report (table 17), but suspended-sediment data have not been evaluated.

The chemical quality of water is derived from many different sources of solutes, such as gases and material from the atmosphere; weathering of sediment, soil, and rocks; chemical and physical reactions; and materials introduced into the hydrologic environment by human activities. McNeely and others (1979) and Hem (1989) provide a comprehensive review of the origins, controls, and significance of the properties and constituents related to the chemical quality of water.

The chemical quality of water is characterized by its dissolved ionic composition, which consists of a balance of cations (positively charged ions) and anions (negatively charged ions). Ionic composition of the ground water and surface water on or near the reservation is similar to the ionic composition of most natural waters. The major cations are calcium, magnesium, and sodium; and major anions are bicarbonate, sulfate, and chloride. In this report, ionic compositions are used to describe the general type of water, with a dominant cation or anion representing more than 50 percent of the total concentration of cations or anions. If no cations or anions are dominant, ionic compositions are described in decreasing order of occurrence for the major cations and anions. The ionic compositions of selected chemical analyses of surface-water samples are presented graphically (Stiff, 1951) later in this report.

The physical properties of water are important indicators of water quality and consist of water temperature, specific conductance, pH, and turbidity. Water temperature is an important factor affecting biological, physical, and chemical processes in water. For example, biological activity, saturation levels of gases, and solubility of minerals in water are affected by temperature. Specific conductance is a measure of the ability of water to conduct an electrical current. Specific conductance is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm) and is a function of the type and concentration of dissolved solids in the water. The hydrogen-ion activity is described by its pH. The pH is defined as the negative logarithm of the hydrogen-ion concentration expressed in moles per liter. In most aqueous solutions, pH generally ranges from 0 to 14. A pH greater than 7 indicates the water is alkaline, and a pH less than 7 indicates the water is acidic.

Water Quality in Relation to Water Use

An important purpose in studying and describing the quality of water is to determine if the water is satisfactory or suitable for a proposed use. Various water-quality standards, tolerances, and guidelines have been established for different water uses (Hem, 1989, p. 210). Because primary water use on the reservation includes public-supply, domestic, and agricultural uses, specific water-quality regulations, standards, and guidelines associated with these water uses are described in the following sections.

Public-Supply and Domestic Use

Water used for public-supply and domestic uses should be chemically safe for human consumption. The water should have no hardness problems and no undesirable physical properties such as color, turbidity, and unpleasant taste or odor (Hem, 1989, p. 210).

The U.S. Environmental Protection Agency (1990, p. 31, 41-43) has established primary and secondary drinking-water regulations pertinent for public supplies of drinking water. These Federal regulations are listed in table 9. The regulations specify maximum contaminant levels (MCLs) and secondary maximum contaminant levels (SMCLs). Primary drinking-water regulations are based on MCLs of constituents that are health related, legally enforceable, and apply within Wyoming, which has adopted the Federal regulations. The secondary drinking-water regulations are based on SMCLs of constituents that primarily affect the aesthetic qualities and the public's acceptance of the drinking water, such as taste or odor. For example, drinking water containing chloride concentrations exceeding the SMCL of 250 mg/L (milligrams per liter) might impart a salty taste. SMCLs have no legally enforceable requirements.

Hardness is another water-quality property important to the public-supply and domestic use of water. Hardness is a calculated value based on the concentrations of calcium and magnesium and is reported as mg/L of calcium carbonate (CaCO₃). Hardness represents the soap-consuming capacity of water as well as the tendency to leave a mineralized crust on plumbing fixtures. Hardness has been characterized on the basis of the following classes (Hem, 1989, p. 158-159)

Hardness as CaCO ₃ (mg/L)	Hardness classes
0-60	Soft
61-120	Moderately hard
121-180	Hard
more than 180	Very hard

Agricultural Use

Agricultural use of water includes irrigation of crops and water consumed by livestock. The chemical quality of water is an important factor when evaluating its usefulness for irrigation. Chemical-quality characteristics that need to be considered include concentrations of potentially toxic constituents, total concentration of dissolved solids in water, and the relative proportion of some of the constituents present. Water used by livestock is subject to quality limitations similar to those for drinking water for human consumption. However, most animals can tolerate water that has higher dissolved-solids concentration than that which is recommended for humans (Hem, 1989, p. 213).

The State of Wyoming has established specific water-quality standards for agricultural (irrigation of crops) and livestock use of ground water (Wyoming Department of Environmental Quality, 1980, p. 1-13). These water-quality standards include some common constituents and selected trace-elements, oil and grease, and radiochemical constituents. A partial list of these water-quality standards for each use is listed in table 10.

A classification system to evaluate the suitability of water for irrigation use was developed by the U.S. Salinity Laboratory Staff (1954). This classification system is based on the salinity-hazard and sodium (alkali) hazard of the water.

Table 9. Primary and secondary drinking-water regulations for public-water supplies

[From U.S. Environmental Protection Agency, 1990, p. 31, 41-43; all constituent concentrations are in milligrams per liter unless otherwise indicated; µg/L, micrograms per liter; N, nitrogen; --, no established regulation or not applicable; pCi/L, picocuries per liter; mrem/yr, milliroentgen equivalent man per year]

	Maximum contaminant level	Secondary maximum contaminant level		race-element ation (μg/L)
Constituent	(MCL)	(SMCL)	MCL	SMCL
	Common cons	tituents		
Dissolved solids		500		
Chloride		250		
Fluoride	4.0	2.0		
Nitrate as N	10			
Sulfate		250		
	Trace elem	ients		
Arsenic	0.05		50	
Barium	1		1,000	
Cadmium	.01		10	
Chromium	.05		50	
Iron		.3		300
Lead	.05		50	
Manganese		.05		50
Mercury	.002		2	
Selenium	.01		10	
Silver	.05		50	
	Pesticid	es		
2,4-D	0.1			
Endrin	.0002			
Lindane	.004			
Methoxychlor	.1			
Toxaphene	.005			
2,4,5-TP Silvex	.01			
	Radiochemical co	onstituents		
Gross alpha particle activity (pCi/L)	15			
Gross beta particle activity (mrem/yr)	4			
Radium 226 and 228, total (pCi/L)	5			

Table 10. State of Wyoming water-quality standards of ground water for agricultural and livestock use

[From Wyoming Department of Environmental Quality, 1980, p. 9; all constituent concentrations are in milligrams per liter unless otherwise indicated; µg/L, micrograms per liter; --, no established standard or not applicable; pCi/L, picocuries per liter]

	Agricultural use		Equivalent tr	
Constituent	(irrigation)	Livestock use	Agricultural use	Livestock use
	Con	nmon constituents		
Dissolved solids	2,000	5,000		
Chloride	100	2,000		
Sulfate	200	3,000		
	מ	Trace elements		
Arsenic	0.1	0.2	100	200
Boron	.75	5.0	750	5,000
Cadmium	.01	.05	10	50
Iron	5.0		5,000	
Lead	5.0	.1	5,000	100
Manganese	.2		200	
Selenium	.02	.05	20	50
	Ot	her constituents		
Oil and grease	10	10		
Uranium	5.0	5.0		
Radium 226 and 228, combined total (pCi/L)	5.0	5.0		

Salinity-hazard is divided into four classes on the basis of specific conductance of the water. Specific conductance, a good indicator of dissolved-solids concentration, is used as a measure of salinity because specific conductance is easily measured and values are commonly available. The specific-conductance range and characteristics of the salinity-hazard classes are as follows (U.S. Salinity Laboratory Staff, 1954, p. 79-81):

Salinity-hazard class	Specific conductance (μS/cm) ¹	Characteristics
Low	0-250	Low-salinity water can be used for irrigation on most soil with minimal likelihood that soil salinity will develop.
Medium	251-750	Medium-salinity water can be used for irrigation if a moderate amount of drainage occurs.
High	751-2,250	High-salinity water is not suitable for use on soil with restricted drainage. Even with adequate drainage, special management for salinity control may be required.
Very high	More than 2,250	Very high-salinity water is not suitable for irrigation under normal conditions.

¹μS/cm, microsiemens per centimeter at 25 degrees Celsius.

Sodium-hazard also is divided into four classes on the basis of sodium-adsorption ratio (SAR) and specific conductance of the water (U.S. Salinity Laboratory Staff, 1954, p. 79-80). SAR is a calculated value determined by the milliequivalents of sodium, calcium, and magnesium and is reported as a dimensionless ratio. Classifying irrigation water with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. The characteristics of the sodium-hazard classes are as follows (U.S. Salinity Laboratory Staff, 1954, p. 81):

Sodium-hazard class	Characteristics
Low	Low-sodium water can be used for irrigation on most soil with minimal danger of harmful levels of exchangeable sodium.
Medium	Medium-sodium water will present an appreciable sodium hazard in fine-textured soil having high cation-exchange capacity.
High	High-sodium water may produce harmful levels of exchangeable sodium in most soil.
Very high	Very high-sodium water is generally unsatisfactory for irrigation purposes.

GROUND-WATER QUALITY

Ground-water quality is affected principally by the following factors: (1) the chemical composition of the water entering the geologic unit, (2) lithological composition and hydrologic properties of the geologic unit, and (3) the residence time of water flowing through the geologic unit. Each of these factors affects the type and quantity of material that is contained in the ground water.

Water-quality data from chemical analyses of water samples from about 300 wells and springs and specific-conductance measurements of water samples from about 450 wells and springs were evaluated to determine the chemical-quality characteristics of water in selected geologic units on the reservation. The chemical-quality characteristics evaluated and summarized herein were related primarily to public-supply, domestic, agricultural, and livestock uses of ground water, and to the classification of ground water as a potential source for irrigation. Selected chemical-quality data from wells and springs evaluated and summarized in this report are tabulated in a report by Daddow (1992). Selected chemical-quality data from wells and springs have been summarized in this report on the basis of the following geologic-unit groups: flood-plain alluvium in four drainage basins (table 11); slope wash and alluvium, terrace deposits, glacial deposits, volcaniclastic rocks, and Tertiary Wind River Formation (table 12); and selected Mesozoic and Paleozoic rocks (table 13).

Linear-regression analysis was used to evaluate dissolved-solids concentration in relation to specific conductance of water samples collected from wells and springs in geologic units that had chemical analyses for seven or more water samples. The results of this type of analysis allows estimation of the dissolved-solids concentration of a ground-water sample by measuring the specific conductance of that sample. The number of samples, range of years that samples were collected, maximum and minimum values of specific conductance, and linear-regression statistics and equations for the selected geologic units are listed in table 14. Residual plots were completed on all data sets to check for outliers and to verify the linearity and variance conditions of the data values. All the calculated regression coefficients (slopes) were significant at the $\alpha = 0.05$ level or less. The squared correlation coefficient (r^2) is a measure of the linear correlation between the response (dependent) variable (dissolved-solids concentration) and the explanatory (independent) variable (specific conductance). The r^2 values can range from 0 to 1; a 0 indicates no correlation and a 1 indicates perfect correlation. For example, an r^2 value of 0.900 indicates that 90 percent of the variation of the dependent (response) variable can be explained by variation in the independent (explanatory) variable. An r^2 value in the range of 0.900 to 1 indicates there is a very good correlation of specific conductance to dissolved-solids concentration in a water sample.

Table 11. Summary of selected water-quality data for wells completed in flood-plain alluvium, Wind River Indian Reservation, Wyoming

[Water-quality constituent: values in milligrams per liter, except as indicated; µS/cm, microsiemens per centimeter at 25 degrees Celsius; CaCO₃, calcium carbonate; dissolved solids, sum of the constituents]

Water-quality constituent or physical property	Data type	Wind River flood-plain alluvium	Little Wind River flood-plain alluvium	Popo Agie River flood-plain alluvium	Owl Creek flood-plain alluvium
Specific conductance (μS/cm)	Samples	34	86	9	5
	Range	270-1,790	110-2,500	275-1,600	1,200-2,710
	Median	659	760	850	2,010
Hardness as CaCO ₃	Samples	19	38	4	7
	Range	3-455	38-925	93-473	38-1,210
	Median	262	241	258	454
Calcium	Samples	18	38	4	7
	Range	1-128	12-204	34-130	10-285
	Median	72	58	67	110
Magnesium	Samples	19	38	4	7
	Range	0.2-40	2-101	2-40	3-121
	Median	15	24	20	43
Sodium	Samples	19	38	4	5
	Range	12-243	4-500	10-84	89-620
	Median	28	53	33	230
Alkalinity as CaCO ₃	Samples	19	37	4	7
	Range	154-431	90-336	100-333	148-385
	Median	256	231	160	263
Sulfate	Samples	19	38	4	7
	Range	15-495	5-1,000	16-305	380-1,060
	Median	85	126	149	810
Chloride	Samples	19	38	4	7
	Range	2-64	2-105	5-6	6-30
	Median	7	12	5	15
Fluoride	Samples	18	37	4	7
	Range	0.1-1.2	0.1-1.6	0.12-0.58	0.2-1.5
	Median	0.3	0.5	0.25	0.7
Dissolved solids	Samples	19	38	4	7
	Range	214-1,230	109-1,720	132-767	828-1,880
	Median	395	424	389	1,310

Ground water is the primary water source on the reservation for public-supply and domestic uses. Hardness is an important water-quality characteristic related to these water uses, and hardness concentrations of water samples from selected geologic units were characterized on the basis of hardness classes previously described in this report. The total number of water samples and the number of water samples in each hardness class for selected geologic units are listed in table 15.

Although surface water from streams is the primary water source for irrigation on the reservation, in some areas ground water could be used on a limited basis as a supplemental source for irrigation. Chemical analyses of water samples from wells and springs from selected geologic units were characterized on the basis of the salinity-hazard and sodium-hazard classes described previously in this report. These hazard classes were used to evaluate the suitability of water for irrigation use (U.S. Salinity Laboratory Staff, 1954). The total number of water samples and the number of water samples in each salinity-hazard and sodium-hazard class from selected geologic units are listed in table 15.

Table 12. Summary of selected water-quality data for wells completed in and springs flowing from slope wash and alluvium, terrace deposits, glacial deposits, volcaniclastic rocks, and the Wind River Formation, Wind River Indian Reservation, Wyoming

[Water-quality constituent: values in milligrams per liter, except as indicated; μ S/cm, microsiemens per centimeter at 25 degrees Celsius; CaCO₃, calcium carbonate; dissolved solids, sum of the constituents; --, not applicable]

Water-quality			Quaternary		Terti	ary
constituent or physical property	Data type	Slope wash and alluvium	Terrace deposits	Glacial deposits	Volcaniclastic rocks	Wind River Formation
Specific conductance (μS/cm)	Samples	31	26	4	3	205
	Range	640-5,500	340-1,720	120-490	302-380	202-14,000
	Median	2,400	585	272	314	869
Hardness as CaCO ₃	Samples	16	18	3	3	154
	Range	137-2,530	166-805	91-171	116-146	2-2,020
	Median	703	213	156	133	30
Calcium	Samples	16	18	3	3	149
	Range	42-600	35-146	30-52	31-37	1-486
	Median	176	48	46	37	10
Magnesium	Samples	16	18	3	3	128
	Range	8-250	12-107	4-10	9-13	0.1-195
	Median	74	21	10	10	2.2
Sodium	Samples	16	18	3	3	153
	Range	9-1,100	7-189	6-43	19-34	5-1,500
	Median	280	39	18	29	150
Alkalinity as CaCO ₃	Samples	15	16	3	3	154
	Range	150-424	156-464	86-139	152-203	44-1,460
	Median	280	236	97	163	166
Sulfate	Samples	16	18	3	3	154
	Range	226-2,600	15-788	2-145	10-10	2-3,250
	Median	952	53	52	10	201
Chloride	Samples	16	18	3	3	154
	Range	5-99	1-58	4-14	0.9-1.2	2-466
	Median	20	7	12	1.1	14
Fluoride	Samples Range Median	16 0.3-1.5 0.9	18 0.5-1.4 0.9	2 0.2-0.2	3 0.2-0.2 0.2	154 0.1-8.8 0.7
Dissolved solids	Samples	16	18	3	3	154
	Range	484-4,630	204-1,330	109-322	197-244	211-5,110
	Median	1,730	338	235	206	490

Quaternary Deposits

The chemical quality of water in the following Quaternary deposits was evaluated: Wind River flood-plain alluvium, Little Wind River flood-plain alluvium, Popo Agie River flood-plain alluvium, Owl Creek flood-plain alluvium, slope wash and alluvium, terrace deposits, and glacial deposits. Chemical-quality analyses of water samples from wells completed in the flood-plain alluvium were grouped, evaluated, and summarized by the major drainage basins on the reservation.

Wind River Flood-plain Alluvium

The chemical quality of water in the Wind River flood-plain alluvium was evaluated on the basis of chemical analyses of 18 or 19 water samples and 34 specific-conductance measurements of water samples collected from selected wells (table 11). Dissolved-solids concentrations ranged from 214 to 1,230 mg/L, with

Table 13. Summary of selected water-quality data for wells completed in and springs flowing from selected Mesozoic and Paleozoic rocks, Wind River Indian Reservation, Wyoming

[Water-quality constituent: values in milligrams per liter, except as indicated; µS/cm, microsiemens per centimeter at 25 degrees Celsius; CaCO₃, calcium carbonate; dissolved solids, sum of the constituents]

			Mesozo	ic rocks		Paleozoic rocks
Water-quality constituents physical property	Data type	Cody Shale	Frontier Formation	Cloverly Formation	Chugwater Group	Phosphoria Formation and related rocks
Specific conductance (μS/cm)	Samples	12	25	5	9	4
	Range	660-6,000	240-8,500	445-1,600	400-2,420	550-4,230
	Median	2,380	2,340	1,190	1,200	3,150
Hardness as CaCO ₃	Samples	8	16	5	7	4
	Range	27-3,380	51-1,840	16-840	190-1,600	279-1,820
	Median	1,080	232	376	585	904
Calcium	Samples	8	16	5	7	4
	Range	8-535	1-409	3-231	41-570	54-447
	Median	240	56	83	160	270
Magnesium	Samples	8	16	5	7	4
	Range	2-496	0.1-199	2-64	17-82	35-171
	Median	116	22	41	44	56
Sodium	Samples	8	16	5	7	4
	Range	37-595	21-1,600	12-370	6-43	4.3-557
	Median	344	270	62	18	400
Alkalinity as CaCO ₃	Samples	6	16	4	7	4
	Range	220-565	135-894	76-573	140-215	237-602
	Median	349	248	299	180	324
Sulfate	Samples	8	16	5	7	4
	Range	89-3,480	33-3,700	113-744	24-1,500	54-2,320
	Median	1,450	478	219	420	1,230
Chloride	Samples	8	16	5	7	4
	Range	5.4-182	2.7-116	5.2-30	1.8-18	1.3-219
	Median	16	18	15	9.6	50
Fluoride	Samples	8	16	5	7	4
	Range	0.1-2.5	0.3-3.8	0.2-2.2	0.1-0.6	0.3-2.1
	Median	0.6	1.4	0.5	0.4	0.8
Dissolved solids	Samples	8	16	5	7	4
	Range	451-5,250	182-6,060	253-1,240	219-2,240	302-3,690
	Median	2,540	1,170	800	824	2,430

a median value of 395 mg/L. Five of 19 samples exceeded the SMCL for dissolved-solids concentration (500 mg/L) and 1 of 19 samples exceeded the SMCL for sulfate (250 mg/L). Hardness class was hard or very hard for 18 of 19 samples (table 15). Salinity-hazard class was medium or high for all 34 samples. Sodiumhazard class was low for 16 of 18 samples. The linear-regression of dissolved-solids concentration in relation to specific conductance for water samples collected from this geologic unit has an r^2 value of 0.983 (table 14).

The ionic compositions of most water samples were dominated by calcium and bicarbonate ions. Samples with dissolved-solids concentrations of more than 500 mg/L generally had mixed ionic compositions of sodium and calcium cations, and bicarbonate and sulfate anions. No downgradient changes were noticeable in the chemical quality of water samples in this geologic unit.

Table 14. Linear-regression analyses of dissolved-solids concentration in relation to specific conductance for water samples from wells completed in and springs Range of specific conductance, minimum and maximum values of specific conductance used to develop the linear-regression equation; DS, dissolved-solids concentration, sum of constituents, in flowing from selected geologic units, Wind River Indian Reservation, Wyoming

milligrams per liter; SC, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; *, multiply by]

		Range of			Linear-regression statistics	sion statistics		
		years	Banda			Societa		
Geologic unit ¹	Number of samples ²	samples were	specific- conductance values ²	Regression coefficient (slope)	Regression constant (y-intercept)	Squared correlation coefficient (r^2)	Standard error of estimate	Linear-regression equation
			Qual	Quaternary deposits				
Wind River flood-plain alluvium	18	1948-90	270-1,790	0.688	-45.9	0.983	31.0	DS = 0.688 * SC - 45.9
Little Wind River flood-plain alluvium	37	1985-89	200-2,200	.791	-111	.965	87.4	DS = 0.791 * SC - 111
Slope wash and alluvium	15	1965-89	736-4,920	.995	-399	886.	118	DS = 0.995 * SC - 399
Terrace deposits	18	1965-89	390-1,710	787.	-105	.973	47.4	DS = 0.787 * SC - 105
			Ī	Tertiary rocks				
Wind River Formation	151	1945-90	350-6,300	.785	-130	976.	8.66	DS = 0.785 * SC - 130
			M	Mesozoic rocks				
Cody Shale	«	1945-90	721-6,000	756.	-312	.975	274	DS = 0.957 * SC - 312
Frontier Formation	16	1945-90	240-7,650	.840	-209	886.	197	DS = 0.840 * SC - 209
Chugwater Group	7	1978-90	400-2,420	.857	-159	.890	243	DS = 0.857 * SC - 159

For flood-plain alluvium, geographic location (drainage area) also is included.

²Number of samples and range of specific-conductance values listed in this table may not be the same as the number of samples and range of specific-conductance values listed in tables 11, 12 or 13 had both specific-conductance and dissolved-solids values.

Table 15. Number of water-quality samples in hardness, salinity-hazard, and sodium-hazard classes for selected geologic units, Wind River Indian Reservation, Wyoming, through 1990

[Hardness, salinity-hazard, and sodium-hazard classes--see report text for description of different classes]

		Hard	Hardness classes	ses			Salinit	Salinity-hazard classes	asses			Sodium	Sodium-hazard classes	asses	
	nu)	(number of sa	samples	imples by class)	(s	u)	ımber o	(number of samples by class)	by class	_	nu)	mber o	(number of samples by class)	by class	_
			Moder-												
Geologic unit ¹	Total samples	Soft	ately hard	Hard	Very hard	Total samples	Low	Medium	High	Very high	Total samples	Low	Medium	High	Very high
						Quaternary deposits	y deposit	S							
Wind River flood-plain alluvium	19	-	0	4	4	34	0	21	13	0	18	16	1	0	1
Little Wind River flood- plain alluvium	38	1	3	∞	26	98	7	36	41	2	37	35	-	0	1
Popo Agie River flood- plain alluvium	4	0	2	0	7	6	0	4	ς.	0	4	4	0	0	0
Owl Creek flood-plain alluvium	7	-	0	-	2	5	0	0	8	2	8	7	-	-	1
Slope wash and alluvium	16	0	0	-	15	31	0	2	13	16	15	12	2	0	-
Terrace deposits	18	0	0	2	16	26	0	16	10	0	18	17	1	0	0
Glacial deposits	3	0	-	2	0	4	2	2	0	0	κ	3	0	0	0
						Tertiary rocks	rocks								
Volcaniclastic rocks	3	0	-	2	0	8	0	3	0	0	33	3	0	0	0
Wind River Formation	154	91	10	∞	45	205	-	9/	107	21	150	36	22	35	57
						Mesozoic rocks	c rocks								
Cody Shale	∞	-	-	0	9	12	0	2	4	9	∞	2	4	-	1
Frontier Formation	16	4	0	2	10	25	1	2	∞	14	16	4	5	2	5
Cloverly Formation	5	1	0	1	3	5	0	7	3	0	S	4	0	0	1
Chugwater Group	7	0	0	0	7	6	0	2	2	2	7	7	0	0	0
						Paleozoic rocks	c rocks								
Phosphoria Formation and related rocks	4	0	0	0	4	4	0	-	0	3	4	-	ю	0	0

 $^{\rm l}{\rm For}$ flood-plain alluvium, geographic location (drainage area) also is included.

Little Wind River Flood-plain Alluvium

The chemical quality of water in the Little Wind River flood-plain alluvium was evaluated on the basis of chemical analyses of 37 or 38 water samples and 86 specific-conductance measurements of water samples collected from selected wells (table 11). Dissolved-solids concentrations ranged from 109 to 1,720 mg/L, with a median value of 424 mg/L. Fifteen of 38 samples exceeded the SMCL for dissolved-solids concentration and 17 of 38 samples exceeded the SMCL for sulfate. Hardness class was hard or very hard for 34 of 38 samples (table 15). Salinity-hazard class was medium or high for 77 of 86 samples. Sodium-hazard class was low for 35 of 37 samples. The linear-regression of dissolved-solids concentration in relation to specific conductance for water samples collected from this geologic unit has an r^2 value of 0.965 (table 14).

Chemical quality of water in the Little Wind River flood-plain alluvium changes as the water moves downgradient in the direction of the rivers. Water samples collected from most wells in the upper section of the Little Wind River flood-plain alluvium from the base of the Wind River Range to about 2 mi upstream from Fort Washakie had ionic compositions dominated by calcium and bicarbonate ions, with dissolved-solids concentrations generally less than 400 mg/L. Most of the water recharging the flood-plain alluvium in this section comes from surface-water sources from mountainous areas. Samples from most wells in the vicinity of Fort Washakie had ionic compositions of calcium, magnesium, and sodium cations with mostly bicarbonate anions and dissolved-solids concentrations generally less than 600 mg/L. In the downstream section of the Little Wind River flood-plain alluvium from about Ethete to Arapahoe, water samples had ionic compositions of predominately sodium, calcium, and sulfate ions, with dissolved-solids concentrations generally greater than 750 mg/L. This downgradient trend in ground-water quality could be caused by lithologic changes in flood-plain alluvium, a downgradient increase in recharge from irrigation return flow, or by the increased contact time of water or seepage of water from the underlying Cody Shale and Frontier Formation as the water moves downgradient. Both the Cody Shale and Frontier Formation have substantial amounts of soluble minerals that can be dissolved in the ground water.

Popo Agie River Flood-plain Alluvium

The chemical quality of water in the Popo Agie River flood-plain alluvium was evaluated on the basis of chemical analyses of four water samples and nine specific-conductance measurements in water samples collected from selected wells (table 11). Dissolved-solids concentrations ranged from 132 to 767 mg/L, with a median value of 389 mg/L. Two of four samples exceeded the SMCL for dissolved-solids concentration and sulfate. Hardness class was very hard for two of four samples (table 15). Salinity-hazard class was medium or high for all nine samples. Sodium-hazard class was low for all four samples.

Chemical quality of the water in the Popo Agie flood-plain alluvium changes as it moves downgradient in the direction of the river. The upper section of the flood-plain alluvium, from the base of the Wind River Range to near the intersection of U.S. Highway 287 is underlain by terrace deposits. Most of the water recharging this upper section of flood-plain alluvium comes from surface-water sources from mountainous areas. Water samples collected from two wells in this section had ionic compositions dominated by calcium and bicarbonate ions and had dissolved-solids concentrations of less than 200 mg/L. The flood-plain alluvium downstream from the upper section to Hudson is underlain mostly by the Cody Shale. Samples collected from wells in this section had ionic compositions of mostly calcium, magnesium, and sodium cations with sulfate anions and dissolved-solids concentrations of more than 600 mg/L. The downgradient change in the chemical quality of the water in the Popo Agie River flood-plain alluvium probably is caused by similar effects as described for the Little Wind River flood-plain alluvium.

Owl Creek Flood-plain Alluvium

The chemical quality of water in the Owl Creek flood-plain alluvium was evaluated on the basis of chemical analyses of five or seven water samples and five specific-conductance measurements in water samples collected from selected wells (table 11). Dissolved-solids concentrations ranged from 828 to 1,880 mg/L, with

a median value of 1,310 mg/L. All seven samples exceeded the SMCL for dissolved-solids concentration and sulfate. Hardness class was hard or very hard for six of seven samples (table 15). Salinity-hazard class was high or very high for five samples. Sodium-hazard class varied from low to very high for five samples. The ionic compositions of the water samples were characterized by a mixture of calcium, sodium, and magnesium cations with a dominance of sulfate anions. The Owl Creek flood-plain alluvium on the reservation is underlain mostly by Cody Shale and Frontier Formation.

Ogle (1992, p. 32-43) described and characterized the chemical quality of water in the flood-plain alluvium located about 2 mi upstream and 7 mi downstream of the confluence of the North Fork Owl Creek and South Fork Owl Creek (includes area outside the reservation). Chemical quality of water in these alluvial deposits varies greatly. Dissolved-solids concentrations in 10 samples collected from 6 wells and 1 spring averaged 1,352 mg/L and ranged from 708 to 2,210 mg/L (Ogle, 1992, p. 32). The variability of chemical composition of water samples collected from these seven sites was described by Ogle (1992, p. 36) to be the result of the following potential factors: irrigation in the vicinity of the wells or spring, interconnection with surface water, natural variability of the lithology of the alluvial deposits, or leakage between the underlying aguifers and the alluvial aguifer.

Slope Wash and Alluvium

The chemical quality of water in the slope wash and alluvium was evaluated on the basis of chemical analyses of 15 or 16 water samples and 31 specific-conductance measurements in water samples collected from selected wells (table 12). Dissolved-solids concentrations ranged from 484 to 4,630 mg/L, with a median value of 1,730 mg/L. Fifteen of 16 samples exceeded the SMCL for dissolved-solids concentration and sulfate. Hardness class was very hard for 15 of 16 samples (table 15). Salinity-hazard class was high or very high for 29 of 31 samples. Sodium-hazard class was low for 12 of 15 samples. The linear-regression of dissolved-solids concentration in relation to specific conductance for water samples collected from this geologic unit has an r^2 value of 0.988 (table 14).

Ionic compositions of the water samples from slope wash and alluvium were characterized by a mixture of calcium, sodium, and magnesium cations with a dominance of sulfate anions. The chemical quality of water samples from this geologic unit had no noticeable changes or trends. Most of the water recharging this unit comes from infiltration of precipitation or surface-water seepage in drainage basins typically having ephemeral or intermittent streamflow. Irrigation return flow also is a major recharge source for this unit where irrigation is practiced, such as in the Mill Creek area.

Terrace Deposits

The chemical quality of water in the terrace deposits was evaluated on the basis of chemical analyses of 16 or 18 water samples and 26 specific-conductance measurements in water samples collected from selected wells and springs (table 12). Dissolved-solids concentrations ranged from 204 to 1,330 mg/L, with a median value of 338 mg/L. Five of 18 samples exceeded the SMCL for dissolved-solids concentration. Three of 18 samples exceeded the SMCL for sulfate. Hardness class was very hard for 16 of 18 samples (table 15). Salinity-hazard class was medium or high for all 26 samples. Sodium-hazard class was low for 17 of 18 samples. The linear-regression of dissolved-solids concentration in relation to specific conductance for water samples collected from this geologic unit has an r^2 value of 0.973 (table 14).

Ionic compositions of the water samples collected from terrace deposits were characterized by a mixture of calcium, sodium, and magnesium cations with a dominance of bicarbonate anions. The chemical quality of water samples collected from this geologic unit had no noticeable changes or trends. Most water recharging the terrace deposits is from irrigation return flow.

Glacial Deposits

The chemical quality of water in glacial deposits was evaluated on the basis of chemical analyses of two or three water samples and four specific-conductance measurements in water samples collected from selected wells (table 12). Dissolved-solids concentrations were 109, 235, and 322 mg/L. Hardness class was moderately hard or hard for all three samples. Salinity-hazard class was low or medium for all four samples. Sodium-hazard class was low for all three samples. Ionic compositions of water samples from this geologic unit were dominated by calcium cations with a mixture of bicarbonate and sulfate anions.

Tertiary Rocks

The chemical quality of water in the following selected Tertiary rocks was evaluated: volcaniclastic rocks and Wind River Formation.

Volcaniclastic Rocks

The chemical quality of water in the volcaniclastic rocks was evaluated on the basis of chemical analyses of three water samples and three specific-conductance measurements of water samples collected from selected springs (table 12). Dissolved-solids concentrations were 197, 206, and 244 mg/L. Hardness class was moderately hard or hard, salinity-hazard class was medium, and sodium-hazard class was low for all three samples (table 15). Ionic compositions of the water samples were characterized by a mixture of calcium, sodium, and magnesium cations with a dominance of bicarbonate anions.

Wind River Formation

The chemical quality of water in the Wind River Formation was evaluated on the basis of chemical analyses of 128 to 154 water samples and 205 specific-conductance measurements of water samples collected from selected wells (table 12). Dissolved-solids concentrations ranged from 211 to 5,110 mg/L, with a median value of 490 mg/L. Seventy-three of 154 samples exceeded the SMCL for dissolved-solids concentration and 62 of 154 samples exceeded the SMCL for sulfate. One of 154 samples exceeded the MCL for fluoride (4.0 mg/L). This sample had a fluoride concentration of 8.8 mg/L and was collected from well 4N-4W-15ddc01 which is 43 ft deep and located in the Crowheart area. Ten of 154 samples exceeded the SMCL for fluoride (2.0 mg/L). Hardness class was soft for 91 of 154 samples and very hard for 45 of 154 samples (table 15). Salinity-hazard class was medium or high for 183 of 205 samples and very high for 21 of 205 samples. Sodium-hazard class was variable but the most common class was very high for 57 of 150 samples. The linear-regression of dissolved-solids concentration in relation to specific conductance for water samples from this geologic unit has an r^2 value of 0.979 (table 14).

The chemical quality and ionic composition of water samples collected from the Wind River Formation were variable because this geologic unit has highly variable lithology, permeability, and recharge conditions. Some general changes in ionic composition of water samples were related to changes in dissolved-solids concentration. For most water samples collected from 13 wells that have dissolved-solids concentrations less than 325 mg/L, ionic compositions were mixed calcium and sodium cations with mostly bicarbonate anions. For most of the water samples collected from 69 wells that have dissolved-solids concentrations between 325 and 500 mg/L, and ionic compositions were mostly sodium cations with mixed bicarbonate and sulfate anions. For most of the water samples collected from 72 wells that have dissolved-solids concentrations greater than 500 mg/L, ionic compositions were dominated by sodium and sulfate ions.

Differences in dissolved-solids concentrations and ionic compositions of water samples from wells completed in the Wind River Formation were observed in some specific areas on the reservation. Most of the wells completed in the Wind River Formation near Riverton and Arapahoe had water samples with dissolvedsolids concentrations usually less than 500 mg/L and ionic compositions dominated by sodium cations with mixed sulfate and bicarbonate anions. In the Johnstown Valley area north of Ethete, most water samples collected from 12 wells completed in the Wind River Formation had dissolved-solids concentrations generally less than 750 mg/L and ionic compositions of mostly calcium cations with mixed sulfate and bicarbonate anions. In the Crowheart area, most of the water samples collected from 16 wells completed in the Wind River Formation had dissolved-solids concentrations ranging from about 500 to 1,500 mg/L and ionic compositions dominated by sodium cations with mixed bicarbonate and sulfate anions.

Mesozoic Rocks

The chemical quality of water in the following selected Mesozoic rocks was evaluated: Cody Shale, Frontier Formation, Cloverly Formation, Nugget Sandstone, and Chugwater Group.

Cody Shale

The chemical quality of water in the Cody Shale was evaluated on the basis of chemical analyses of 6 or 8 water samples and 12 specific-conductance measurements in water samples collected from selected wells (table 13). Dissolved-solids concentrations ranged from 451 to 5,250 mg/L, with a median value of 2,540 mg/L. Seven of eight samples exceeded the SMCL for dissolved-solids concentration and sulfate. One of eight samples exceeded the SMCL for fluoride. Hardness class was very hard for six of eight samples (table 15). Salinity-hazard class was high or very high for 10 of 12 samples. Sodium-hazard class was low or medium for six of eight samples. The linear-regression of dissolved-solids concentration in relation to specific conductance for water samples from this geologic unit has an r^2 value of 0.975 (table 14). Ionic compositions of the water samples were a mixture of sodium, magnesium, and calcium cations with a dominance of sulfate anions.

Frontier Formation

The chemical quality of water in the Frontier Formation was evaluated on the basis of chemical analyses of 16 water samples and 25 specific-conductance measurements in water samples collected from selected wells and springs (table 13). Dissolved-solids concentrations ranged from 182 to 6,060 mg/L, with a median value of 1,170 mg/L. Fourteen of 16 samples exceeded the SMCL for dissolved-solids concentration. Thirteen of 16 samples exceeded the SMCL for sulfate. Two of 16 samples exceeded the SMCL for fluoride. Hardness class was very hard for 10 of 16 samples (table 15). Salinity-hazard class was high or very high for 22 of 25 samples. Sodium-hazard class was variable for the samples, ranging from low to very high. The linearregression of dissolved-solids concentration in relation to specific conductance for water samples from this geologic unit has an r^2 value of 0.988 (table 14). Ionic compositions of the water samples change with increasing dissolved-solids concentration. Samples with dissolved-solids concentrations less than 500 mg/L had ionic compositions of mostly calcium, sodium, and bicarbonate ions. Samples with dissolved-solids concentrations greater than 750 mg/L had ionic compositions dominated by sodium and sulfate ions.

Cloverly Formation

The chemical quality of water in the Cloverly Formation was evaluated on the basis of chemical analyses of four or five water samples and five specific-conductance measurements collected from selected wells (table 13). Dissolved-solids concentrations ranged from 253 to 1,240 mg/L, with a median value of 800 mg/L. Three of five samples exceeded the SMCL for dissolved-solids concentration. Two of five samples exceeded the SMCL for sulfate. One of five samples exceeded the SMCL for fluoride. Hardness class was very hard for three of five samples. Salinity-hazard class was medium or high for all five samples. Sodium-hazard class was low for four of five samples. Ionic compositions of the water samples were a mixture of calcium, magnesium, and sodium cations with bicarbonate and sulfate anions.

Nugget Sandstone

The chemical quality of water in the Nugget Sandstone consisted of a chemical analysis of a water sample collected from one well. This well (1S-2W-24dcb03) is 63 ft deep and about one-fourth of a mile from an outcrop of the Nugget Sandstone on the east flank of the Wind River Range in the Trout Creek area southwest of Ethete. The dissolved-solids concentration of the sample was 327 mg/L. Hardness class was very hard, salinity-hazard class was medium, and sodium-hazard class was low for this sample. Ionic composition of the water sample was dominated by calcium and bicarbonate ions. Richter (1981, p. 105-106) reported that dissolved-solids concentrations of water samples from this geologic unit are generally greater than 1,000 mg/L except from wells and springs near outcrops.

Chugwater Group

The chemical quality of water in the Chugwater Group was evaluated on the basis of chemical analyses of seven water samples and nine specific-conductance measurements in water samples collected from selected wells and springs (table 13). Dissolved-solids concentrations ranged from 219 to 2,240 mg/L, with a median value of 824 mg/L. Five of seven samples exceeded the SMCL for dissolved-solids concentration and sulfate. Hardness class was very hard for all seven samples (table 15). Salinity-hazard class was high for five of nine samples. Sodium-hazard class was low for all seven samples. The linear-regression of dissolved-solids concentration in relation to specific conductance for water samples collected from this geologic unit has an r^2 value of 0.890 (table 14). Ionic compositions of the water samples change with increasing dissolved-solids concentration. Samples with dissolved-solids concentrations less than 300 mg/L had mostly calcium and bicarbonate ions. Samples with dissolved-solids concentrations greater than 600 mg/L were dominated by calcium and sulfate ions.

Paleozoic Rocks

The chemical quality of water in the following selected Paleozoic rocks was evaluated: Phosphoria Formation and related rocks, Tensleep Sandstone, and Madison Limestone.

Phosphoria Formation and related rocks

The chemical quality of water in the Phosphoria Formation and related rocks was evaluated on the basis of chemical analyses of four water samples and four specific-conductance measurements collected from selected wells and one spring (table 13). Dissolved-solids concentrations for the water samples from the wells were 1,650, 3,200, and 3,690 mg/L. Dissolved-solids concentration for the water sample from the spring was 302 mg/L. The three samples from the wells exceeded the SMCL for dissolved-solids concentration and sulfate. One sample from a well exceeded the SMCL for fluoride. Hardness class was very hard for all four samples. Salinity-hazard class was very high, and sodium-hazard class was medium for the three samples from the wells. Ionic compositions of the samples collected from the wells were a mixture of sodium, calcium and magnesium cations with a dominance of sulfate anions. Ionic composition of the sample from the spring was mostly magnesium and calcium cations with a dominance of bicarbonate anions.

Tensleep Sandstone

Water-quality data from water-supply wells completed in and springs flowing from the Tensleep Sandstone on or near the reservation are limited in quantity and scope. The chemical quality of water samples from three flowing wells and one spring was evaluated. Water samples were collected from three flowing wells completed in the Tensleep Sandstone located on the east flank of the Wind River Range about 3 mi south of the reservation. Dissolved-solids concentrations of water samples ranged from 212 to 232 mg/L for the three wells. Hardness class was very hard, salinity-hazard class was medium, and sodium-hazard class was low for all three samples. A water sample was collected in May 1945, July 1968, September 1989, and October 1989 from Washakie Mineral Hot Springs (1S-1W-02aad01). The primary water source for this spring is the Tensleep Sandstone, but the Phosphoria Formation also may be contributing water. Dissolved-solids concentrations of these four samples ranged from 690 to 801 mg/L. The SMCLs for dissolved-solids concentration and sulfate were exceeded in all four samples. Three out of four samples exceeded the SMCL for fluoride. Hardness class was very hard, salinity-hazard class was high, and sodium-hazard class was low for all four samples. Ionic compositions of the water samples were dominated by calcium and bicarbonate ions.

Richter (1981, p. 100-102) summarized the chemical quality of the water in the Tensleep Sandstone on the basis of 25 chemical analyses of the samples collected from water-supply wells, springs, and mostly oil-andgas wells in the Wind River Basin. Samples from wells and springs collected near outcrops of this formation were characterized as having dissolved-solids concentrations less than 500 mg/L, hardness less than 180 mg/L, and ionic compositions of mostly calcium, magnesium, and bicarbonate ions. With increasing well depths, water samples from this unit had dissolved-solids concentrations greater than 3,000 mg/L, with ionic compositions dominated by sodium and sulfate ions.

Cooley (1986) summarized the chemical quality of the Tensleep Sandstone in the Ten Sleep area in southeastern Bighorn Basin, Wyoming. This area is on the southwestern flanks of the Bighorn Mountains and has hydrogeologic conditions similar to the east flank of the Wind River Range. The chemical quality of water samples from wells completed in the Tensleep Sandstone had the following characteristics (Cooley, 1986, p. 49):

Range, in milligrams per liter
42-59
150-272
14-29
2-12
2-60
164-272

Madison Limestone

Water-quality data from water-supply wells completed in and springs flowing from the Madison Limestone on or near the reservation are limited in quantity and scope. The chemical quality of water in the Madison Limestone was evaluated on the basis of chemical analyses of water samples and specific-conductance measurements in water samples collected from three wells and one spring.

Of the three water-supply wells, two are within and one is near the reservation. The water sample from industrial water-supply well 2S-2E-19ccc01, which is 2,930 ft deep and is located in the Lander-Hudson oil field, had a dissolved-solids concentration of 230 mg/L. The temperature of this water sample was 26.0°C, which is at least 10°C hotter than most ground-water samples from wells and springs on the reservation. Hardness class was very hard, salinity-hazard class was medium, and sodium-hazard class was low for this

sample. Ionic composition of this water sample was dominated by calcium and bicarbonate ions. The water sample from industrial water-supply well 2N-1W-18ccc01, which is 4,210-ft deep and is located in the Winkleman Dome oil field, had a dissolved-solids concentration of 880 mg/L and a water temperature of 62.0°C. This sample exceeded the SMCL for dissolved-solids concentration, sulfate, and fluoride. Hardness class was very hard, salinity-hazard class was high, and sodium-hazard class was low for this sample. Ionic composition of this water sample was mostly calcium and sulfate ions. Another water sample was collected from a flowing well (33N-101W-13aba02) located on the east flank of the Wind River Range about 3 mi south of the reservation. A water sample from this well had a dissolved-solids concentration of 216 mg/L. Hardness class was very hard, salinity-hazard class was medium, and sodium-hazard class was low for this sample. Ionic composition of this water sample was dominated by calcium and bicarbonate ions.

The water sample collected from spring (4N-6W-01aca01), which is located in the Owl Creek Mountains, had dissolved-solids concentration of 210 mg/L. Hardness class was very hard, salinity-hazard class was medium, and sodium-hazard class was low for this sample. Ionic composition of this water sample was dominated by calcium and bicarbonate ions.

Nitrates

Nitrate analyses of water samples collected from wells and springs were evaluated to determine if any samples exceeded the MCL of 10 mg/L for nitrate as N (nitrogen) (table 9). The nitrate data evaluated are listed in Daddow (1992, table 6). In the evaluation of the nitrate data collected from ground-water sites, analyses for nitrite plus nitrate as N were grouped with analyses for nitrate as N. A total of 188 water samples from wells and springs were analyzed for nitrates. Nine samples from wells exceeded or equaled the MCL for nitrate as N. Eight additional samples from wells had nitrate as N concentrations between 5 and 10 mg/L. The 17 water samples collected that had nitrate concentrations of 5 mg/L or more are listed in table 16. Eleven of the 17 samples were collected from wells less than 65 ft deep. Septic tanks, feedlots, barnyards, and nitrate fertilizers are common sources of nitrogen in ground water (National Academy of Sciences and National Academy of Engineering, 1973, p. 73).

Trace Elements

Trace-element analyses of water samples collected from wells and springs (Daddow, 1992, tables 6 and 7) were evaluated to determine if any samples exceeded MCLs for the following constituents: arsenic, barium, cadmium, chromium, mercury, and selenium (table 9). Boron analyses of water samples were evaluated to determine if any samples exceeded the State of Wyoming water-quality standards for agricultural and livestock use of water (table 10).

<u>Arsenic</u>—None of the 35 water samples analyzed for arsenic exceeded the MCL for arsenic (0.05 mg/L). The highest arsenic concentration was 0.026 mg/L from a sample collected at Washakie Mineral Hot Springs (1S-1W-02aad01).

<u>Barium</u>—None of the 14 water samples analyzed for barium exceeded the MCL for barium (1 mg/L). The highest barium concentration was 0.2 mg/L in a sample collected from well 3N-1W-15dda01, which is completed in slope wash and alluvium.

Boron—Seven of 119 water samples analyzed for boron exceeded the State of Wyoming agricultural use water-quality standard for boron (0.75 mg/L). Boron concentrations in these seven samples ranged from 0.78 to 13 mg/L. The highest boron concentration was analyzed in a sample collected from well 1N-1E-35dbb01, which is completed in the flood-plain alluvium. The other six samples were collected from wells completed in the Frontier Formation (3 samples), Wind River Formation (1 sample), slope wash and alluvium (1 sample), and an unknown geologic source (1 sample).

Table 16. Ground-water quality samples collected from wells with nitrate concentrations of 5 milligrams per liter or more, Wind River Indian Reservation, Wyoming

[Local number: township-range-section location, see report text for description of local-numbering system; --, geologic unit is unknown or no available data; well depth, in feet below land surface; ft, feet; N, nitrogen; mg/L, milligrams per liter; data source: IHS, Indian Health Services; USGS, U.S. Geological Survey]

Local number	Geologic unit ¹	Well depth (ft)	Sampling date	Nitrate as N (mg/L)	Nitrite plus nitrate as N (mg/L)	Data source
2N-1E-36bda01	Wind River Formation	135	09-01-81		100	USGS
9N-3E-33adb01	Owl Creek flood-plain alluvium	28	06-23-89		5.3	USGS
1N-1W-30ccb01	Little Wind River flood-plain alluvium	23	10-01-76	5.0		IHS
1N-2W-36aca02	Little Wind River flood-plain alluvium	32	12-11-84	5.2		IHS
3N-1W-15dda01	Slope wash and alluvium	54	09-04-89		95	USGS
3N-1W-15dda02	Slope wash and alluvium	310	10-16-89		79	USGS
4N-4W-08bca01	Wind River Formation	95	08-09-85	8.6		IHS
4N-4W-15ada01	Terrace deposits	60	03-21-85	10		IHS
1S-1E-10ddc03	Frontier Formation	60	05-11-76	12		IHS
1S-1E-17dcc01			10-06-76	7.6		IHS
1S-1E-21add02	Slope wash and alluvium	48	01-19-77	8.0		IHS
1S-1E-27cdd01			07-05-78	12		IHS
1S-1E-28cdd01	Cody Shale	64	04-26-76	10		IHS
1S-2E-10ccc01	Little Wind River flood-plain alluvium	50	11-07-77	10		IHS
1S-1W-15cca01	Frontier Formation	100	06-26-90		5.1	USGS
1S-2W-01caa01	Frontier Formation	51	12-04-78	19		IHS
1S-2W-02ddd02	Little Wind River flood-plain alluvium	47	11-09-84	6.8		IHS

¹For flood-plain alluvium, geographic location (drainage area) also is included.

Cadmium—None of the 14 water samples analyzed for cadmium exceeded the MCL for cadmium (0.01 mg/L). The highest cadmium concentration was 0.001 mg/L from a sample collected from Washakie Mineral Hot Springs (1S-1W-02aad01).

Chromium—None of the 14 water samples analyzed for chromium exceeded the MCL for chromium (0.05 mg/L). The highest chromium concentration was 0.003 mg/L in a sample collected from well 4N-4W-23bab01, which is completed in terrace deposits.

Mercury—None of the 14 water samples analyzed for mercury exceeded the MCL for mercury (0.002 mg/L). The highest mercury concentration was 0.0002 mg/L in a sample collected from well 4N-4W-22adb01, which is completed in Wind River Formation.

Selenium—Two of 45 water samples analyzed for selenium exceeded the MCL for selenium (0.01 mg/L). One sample collected from well 2N-1E-36bda01, which is completed in the Wind River Formation, had a selenium concentration of 0.058 mg/L. A sample collected from well 3N-1W-15dda02, which is completed in slope wash and alluvium, had a selenium concentration of 0.065 mg/L.

Radiochemicals

Radiochemical analyses of water samples collected from wells and springs were evaluated to determine if any samples exceeded 5.0 pCi/L MCL for radium 226 and radium 228. The radiochemical analyses of these water samples are listed in Daddow (1992, table 8, p. 128) and only radium 226 was analyzed for these specific samples. Two of nine water samples analyzed for radium 226 had concentrations higher than 5.0 pCi/L. These two samples were collected at Washakie Mineral Hot Springs (1S-1W-02aad01) and had radium 226 concentrations of 56 and 49 pCi/L. A possible source of radium in these two water samples is the Phosphoria Formation, which contains radiochemical materials and is probably contributing ground water to this spring (J.D. Love, U.S. Geological Survey, oral commun., 1990). Chemical analyses for natural uranium were evaluated to determine if any samples had concentrations exceeding the No-Adverse Response Level for uranium (0.035 mg/L) recommended by the National Academy of Sciences (1983). The largest uranium concentration was 0.032 mg/L in a water sample collected from well 4N-4W-09cad01, which is completed in terrace deposits.

Pesticides

Pesticide analyses of water samples collected from five wells were evaluated to determine if any samples had concentrations greater than the detection limits for the following herbicides: 2,4-D, 2,4,5-T, dicamba, picloram, and silvex; and insecticides: diazinon, ethion, malathion, parathion, and trithion. No herbicides were detected in water samples collected from the five wells: 2N-2E-32ccc01 (completed in Wind River Formation and is 181 ft deep), 4N-4W-09cad01 (completed in terrace deposits and has an unknown depth), 4N-4W-22adb01 (completed in Wind River Formation and is 460 ft deep), 4N-4W-23bab01 (completed in terrace deposits and is 40 ft deep), and 4N-4W-26bcb01 (completed in flood-plain alluvium and is 9 ft deep). No insecticides were detected in water samples collected in two of the five wells (4N-4W-09cad01 and 4N-4W-23bab01), which also were sampled for herbicide analysis. The other three wells listed previously were not sampled for insecticide analysis.

SURFACE-WATER QUALITY

Water-quality data have been collected at streamflow-gaging stations and miscellaneous surface-water sites on or near the reservation since 1947. The data include water-quality properties and chemical analyses of water samples from 33 gaging stations (table 17) and 28 of 39 miscellaneous surface-water sites (table 7). Because of the large quantities of data, the water-quality data from all gaging stations and miscellaneous surface-water sites on or near the reservation have been summarized but not listed in this report. These water-quality data can be obtained from the USGS office in Cheyenne, Wyoming.

Water-quality data through 1990 for 33 streamflow-gaging stations on or near the reservation were summarized as follows: water-quality properties, major constituents, trace elements, sediment, nutrients, bacteria, radiochemicals, and pesticides. The period of record and number of water-quality analyses for each data type are listed in table 17. Data for water-quality properties consist of measurements for specific conductance, pH, water temperature, turbidity, and dissolved oxygen. Major-constituent data consist of analyses for inorganic constituents, which commonly are present in water at concentrations exceeding 1 mg/L, and include calcium, magnesium, sodium, alkalinity, sulfate, and chloride. Trace-element data consist of analyses for minor inorganic constituents such as arsenic, boron, cadmium, iron, mercury, and selenium. Sediment data consist mostly of analyses for suspended-sediment concentration. Nutrient data consist mostly of analyses for nitrate but also include analyses for nitrite, ammonia, and phosphorous. Bacteria data consist primarily of microbiological analyses for fecal coliform and fecal streptococcal bacteria. Radiochemical data include analyses for gross alpha, gross beta, radium 226, and natural uranium. Pesticide data include analyses for selected herbicides and insecticides.

Table 17. Period of record and number of analyses for different types of water-quality data for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990

[Site number: Site number used in this report. Streamflow-gaging station number: See report text for description of the gaging station numbering system. Number of water-quality analyses: Enclosed in parentheses below the period of record for each water-quality type; --, no data]

	Streamflow-		Period of	Period of record by calendar year and (number of water-quality analyses) for period of record	endar year an	d (number o	f water-quali	ty analyses)	for period of	record
Site	gaging		Water-							
number	station	Control of the section of the sectio	quality	Major	Trace	Codimont	N. trions		Radio-	Doctinidae
(piace +)		Streaminow-gaging station	pi opei nes	COLISINGELIES	CICILICATION	Occilion in	אחוו ופוווים	Dacteria	CHEINCAIS	Lesiicides
C1	06220500	East Fork Wind River near Dubois	1975-86 1990	1990	:	1975-86	1990	!	1	1
			(126)	(1)	;	(124)	(1)	}	;	;
G 2	06220800	Wind River above Red Creek, near	1990	1986-90	1987-90	;	1986-90	1	1	1987-90
		Dubois	(2)	(27)	(19)	;	(26)	;	;	(8)
G3	06221400	Dinwoody Creek above lakes, near	1990	1988-90	1988-90	1970	1988-90	;	;	1
		Burris	(1)	(6)	(6)	<u>=</u>	(6)	;	1	;
95	06222500	Dry Creek near Burris	1990	1990	:	1	1990	1	1	1
			(1)	(<u>T</u>)	1	1	(1)	1	ł	1
SS	06222700	Crow Creek near Tipperary	1974-90	1990	1	ł	1990	;	;	1
			(167)	(I)	!	1	(1)	;	:	1
G10	06223500	Willow Creek near Crowheart	1990	0661	;	;	1990	;	;	1
			(\Box)	(I)	}	1	(1)	1	;	;
G13	06224000	Bull Lake Creek above Bull Lake	1974-90	1988-90	1988-90	ļ	1988-90	;	;	1
			(163)	(6)	(6)	1	(6)	;	1	1
G15	06225000	Bull Lake Creek near Lenore	1990	;	;	;	;	1	1	1
			(1)	}	1	}	;	1	;	1
G16	06225500	Wind River near Crowheart	1976 1978 1987-90	1987-90	1987-90	1970-82 1990	1987-90	;	ŀ	1987-90
			(7)	(26)	(17)	(212)	(25)	;	i	(8)
G17	06226000	Wyoming Canal near Lenore	1988	1988	1988	1974-82 1988	1988	1	1	1
			(1)	(1)	(1)	(177)	(1)	;	;	;
G20	06227600	06227600 Wind River near Kinnear	1990	1	;	1990	;	:	1985-90	;
			(9)	1	;	(11)	1	;	(20)	;
G21	06227700	LeClair Canal near Riverton	: :	1 1	: :	1976-77 (12)	1 1	; ;	1 1	1 1
G22	06228000	Wind River at Riverton	1947-50	1947-50	1947-50	1949-51	1947-50	1973-78	1985-90	
			1985-90	06-0061	1986-90	1939-03 1971 1977	06-6061	1980-90		
			(340)	(362)	(246)	1985-90 (265)	(362)	(84)	(20)	!

Table 17. Period of record and number of analyses for different types of water-quality data for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990--Continued

Site number (plate 4) G23 (224 (222) G27 (222) G32 (232) G33 (232)	gaging station number 06228350		Water-							
	station number 06228350 06228450									
	06228350	Streamflow-gaging station	quality properties	Major constituents	Trace elements	Sediment	Nutrients	Bacteria	Radio- chemicals	Pesticides
	06228450	South Fork Little Wind River above	1976-90	1976-90	1988-90	1	1976-90		1	
	06228450	Washakie Keservoir, near Fort Washakie	(130)	(071)	(14)	;	(121)	;	1	;
		South Fork Little Wind River below	1990	1990	;	;	1990	1	1	1
		Washakie Reservoir	(E)	(I)	1	1	\exists	ŀ	1	!
	06228800	North Fork Little Wind River near Fort	1990	1990	1	;	1990	:	1	:
		Washakie	(1)	(1)	;	;	(I)	;	1	1
	06229680	Sage Creek above Norkok Meadows	1990	1990	1	ì	1990	;	;	;
		Creek, near Fort Washakie	(1)	(1)	1	;	(1)	1	1	;
	06229900	Trout Creek near Fort Washakie	1990	1990	;	;	1990	;	;	1
			(-)	Ξ		;	(I)	:	;	:
	06230190	Mill Creek above Ray Lake outlet, near	1990	1990	1990	;	1990	;	;	;
		Fort Washakie	(1)	(E)	(I)	1	(1)	;	;	;
	06230300	Ray Lake outlet near Fort Washakie	1960-70	1960-70	02-0961	+	1961-70	1	1	;
			(37)	(3/)	(37)	1	(32)	1	}	}
	06231000	Little Wind River above Arapahoe	1966-90	1966-90	1966-73	; ;	1966-90	1973-77	1985-90	1988-90
			(180)	(231)	(100)	1	(239)	(61)	(20)	(7)
G39 (06232600	Popo Agie River at Hudson Siding, near	1983-89	1	1989	;	1983-89	1983-89	1	1990
			(42)	1	(3)	!	(41)	(42)	1	(3)
G41 (06233600	Popo Agie River at Hudson	1966-69 1984	1966-69	1966-69	ł	1	1966-69	1	1
			(36)	(35)	(35)	ŀ	:	(35)	1	1
G42 (06233900	Popo Agie River near Arapahoe	1980-84	1980-90	1988-90	1	1983-90	1983	1985-90	1980-90
			(5)	(123)	(24)	;	(102)	(6)	(20)	(59)
G44 (06235000	Beaver Creek near Arapahoe	1951 1967-75 1978-81	1951 1967-81	1951 1967-73 1989-90	1990	1967-81	!	1985-89	i
			(98)	(113)	(53)	(3)	(111)	1	(15)	;
G45 (06235500	Little Wind River near Riverton	1953-54 1965-76 1978-81 1985	1953-54 1965-86	1954 1965-73 1986 1989-90	1959-65 1971 1989-90	1954 1965-89	1987-90	1985-90	1978
			(256)	(309)	(199)	(180)	(313)	(12)	(20)	(2)

 Table 17. Period of record and number of analyses for different types of water-quality data for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990--Continued

	Streamflow-		Period of	Period of record ' by calendar year and (number of water-quality analyses) for period of record	endar year ar	nd (number c	of water-quali	ty analyses)	for period of	record
Site	gaging		Water-							
number	station		quality	Major	Trace				Radio-	
(plate 4)	numper	Streamflow-gaging station	properties	constituents	elements	Sediment	Nutrients	Bacteria	chemicals	Pesticides
G48	06236100	Wind River above Boysen Reservoir, near Shoshoni	1973-90	1973-82 1990	1973-76 1986 1989-90	;	1973-90	1974-89	1	1976-80 1990
			(143)	(105)	(33)	;	(153)	(148)	;	(12)
G49	06239000	Muskrat Creek near Shoshoni	I	ı	ı	1950 1961, 1964 1967-68 1971-73	ı	I	ı	ı
			1	1	1	(33)	;	;	1	1
G50	06244500	Fivemile Creek above Wyoming Canal, near Pavillion	1949-51 1969 1974-75 1988-90	1949-51 1969 1974-75 1988-90	1949-50 1969 1988-90	1949-51 1960-61 1964-68 1970-75 1989-90	1969 1974-75 1987-90	;	1988	1988-90
			(53)	(72)	(20)	(100)	(50)	;	Ξ	(4)
G52	06257500	Muddy Creek near Pavillion	1949-51 1988-90	1949-51 1988-90	1949-51 1988-90	1949-51 1961 1964-68 1970-72	1989-90	ŀ	1988	1989-90
			(11)	(13)	(14)	(63)	(5)	1	(1)	(2)
G53	06259000	Wind River below Boysen Reservoir	1953-54 1956 1960-87	1953-54 1956 1960-90	1953-54 1956 1961-73 1977-90	1979-86	1953-54 1956 1960-87	1973-87	1977-80 1983	1976-80
			(457)	(468)	(313)	(46)	(415)	(147)	(13)	(8)
G54	06260000	South Fork Owl Creek near Anchor	1974-85	1977-78	1977-78	1965 1977-78	1977-78	1977-78	1	1
			(119)	(10)	(10)	(11)	(10)	(6)	;	;
G57	06260400	South Fork Owl Creek below Anchor Reservoir	1974-86 (99)	1 1	1 1	1 1	1 1	1 1	1 1	1 1

¹Period of record may include partial years of records.

Water-quality data through 1990 for 28 miscellaneous surface-water sites were summarized. The year, water-quality type (water-quality properties, nutrients and major constituents, trace elements, radiochemical, and pesticides), and number of water-quality analyses for the miscellaneous surface-water sites are listed in table 7.

Major Chemical Characteristics of Streams

The chemical quality of streams is generally more complex and variable in time and space than the chemical quality of ground water. The chemical quality of streams is constantly changing because of changes in streamflow conditions, and the stream water consists of a mixture of waters that reach the stream from various sources.

Chemical-quality data from 12 selected streamflow-gaging stations were evaluated to determine the long-term, chemical-quality characteristics of streams on or near the reservation. The 12 gaging stations (table 18) were selected because they have 4 years or more of major-constituent analyses. The chemical-quality characteristics of these streams were evaluated and summarized based primarily on public-supply, domestic, agricultural, and livestock uses.

Statistical summaries of the chemical-quality data for these 12 streamflow-gaging stations are presented in appendix 2. These summaries include the sample size; maximum and minimum values; and the 95th, 75th, 50th (median), 25th, and 5th percentiles of the values for the following types of data: water-quality properties, major constituents, major nutrients, selected trace elements, and selected radiochemicals. Statistical summaries are listed only when the sample size of the constituent is 11 or greater. Chemical-quality data less than the constituent detection limit are called censored data and were statistically analyzed using a log-probability regression procedure described by Maddy and others (1990, p. 5-15 to 5-18).

Linear-regression analysis was used to evaluate dissolved-solids concentration in relation to specific conductance of water samples collected from the 12 streamflow-gaging stations. The results of this type of analysis allows estimation of the dissolved-solids concentration of a stream sample by measuring the specific conductance of that sample. The number of samples, range of years that samples were collected, minimum and maximum values of specific conductance used in the regression analyses, and linear-regression statistics and equations are listed in table 19. The regression line and data values used for the regression analyses for two representative gaging stations—Wind River above Red Creek, near Dubois (site G2) and Popo Agie River near Arapahoe (site G42) are shown in figure 7. Residual plots were completed on all data sets to check for outliers and to verify the linearity and variance conditions of the data values. All the calculated regression coefficients (slopes) were significant at the $\alpha = 0.5$ level or less. The r^2 values for 9 of the 12 linear-regression equations determined for water samples from these gaging stations were greater than 0.900. An r^2 value in the range of 0.900 to 1 indicates there is a very good correlation of specific conductance to dissolved-solids concentration in a water sample.

Water from streams on the reservation is used for public-supply and domestic purposes. Hardness is an important chemical-quality characteristic related to these water uses, and hardness concentrations of water samples from the 12 streamflow-gaging stations were characterized on the basis of the hardness classes described previously in the ground-water quality section in this report. The number of water samples in each hardness class for the selected gaging stations are listed in table 20.

Water from streams is the primary water source for irrigation use on the reservation. Chemical analyses of water samples from the selected streamflow-gaging stations were classified on the basis of their salinity-hazard and sodium-hazard classes described previously in the ground-water quality section in this report. These hazard classes are used to evaluate the suitability of water for irrigation use (U.S. Salinity Laboratory Staff, 1954). The number of water samples in each of the salinity-hazard and sodium-hazard classes for the 12 gaging stations are listed in table 20.

Table 18. Selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, with 4 years or more of major-constituent analyses through 1990

[Site number: site number used in this report. Streamflow-gaging station number: see report text for description of the gaging station numbering system]

Site number (plate 4)	Streamflow-gaging station number	Streamflow-gaging station
G2	06220800	Wind River above Red Creek, near Dubois
G16	06225500	Wind River near Crowheart
G22	06228000	Wind River at Riverton
G23	06228350	South Fork Little Wind River above Washakie Reservoir, near Fort Washakie
G34	06230300	Ray Lake outlet near Fort Washakie
G36	06231000	Little Wind River above Arapahoe
G42	06233900	Popo Agie River near Arapahoe
G44	06235000	Beaver Creek near Arapahoe
G45	06235500	Little Wind River near Riverton
G48	06236100	Wind River above Boysen Reservoir, near Shoshoni
G50	06244500	Fivemile Creek above Wyoming Canal, near Pavillion
G53	06259000	Wind River below Boysen Reservoir

Chemical Quality in Relation to Streamflow

Streamflow has a major effect on chemical quality of the streams on or near the reservation. The chemical quality of the water in streams changes rapidly in response to changes in streamflow. At low-flow conditions, streamflow is sustained or at least supplemented by ground-water inflow, and dissolved-solids concentrations typically are greater than at high-flow conditions. Also at low-flow conditions, the velocity of the streamflow generally is slower, which allows the surface water to become more concentrated with dissolved materials from fluvial and geologic deposits. At high-flow conditions, the dissolved-solids concentrations in streams usually are decreased by the dilution effect of increased streamflow from snowmelt and surface runoff. Concentrations of major constituents also vary with changes in streamflow. Colby and others (1956, p. 121-126) describe and provide examples of changes in chemical quality of water samples collected from streams on or near the reservation at different streamflow conditions.

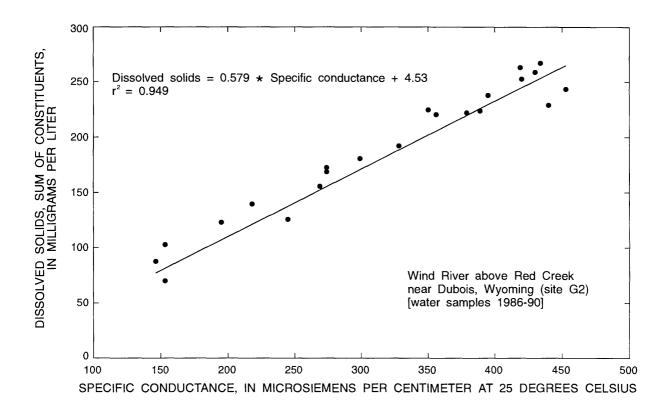
Chemical-quality data from two representative streamflow-gaging stations--South Fork Little Wind River above Washakie Reservoir, near Fort Washakie (site G23) and Little Wind River above Arapahoe (site G36) were used to evaluate the effects of streamflow on chemical quality (fig. 8). Chemical-quality data from these two sites were grouped into three different flow ranges on the basis of flow-duration data listed in appendix 1. The low-flow range consisted of chemical-quality analyses of samples collected at discharges less than the 90th-percentile flow value. The medium-flow range consisted of chemical-quality analyses of samples collected at discharges between the 60th- and 40th-percentile flow values. The high-flow range consisted of chemicalquality analyses of samples collected at discharges greater than the 10th-percentile flow value. The median dissolved-solids concentration decreased with increasing streamflow for both sites. The spread between the lower- and upper-quartile values for the dissolved-solids concentration also changed with streamflow for both sites as shown in the diagrams in figure 8.

Table 19. Linear-regression analyses of dissolved-solids concentration in relation to specific conductance for water samples collected from selected streamflowgaging stations on or near the Wind River Indian Reservation, Wyoming

[Site number: site number used in this report. Streamflow-gaging station number: see report text for description of the gaging station numbering system. Range of specific conductance, minimum and maximum values of specific conductance used to develop the linear-regression equation. Abbreviations: DS, dissolved solids, sum of constituents, in milligrams per liter; SC, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; *, multiply by]

			Range of			Linear-regression statistics	ion statistics		
Site	Streamflow-		years that samples	Range of specific-	Regression	Regression	Squared correlation	Standard	ı
number (plate 4)	gaging station number	Number of samples ¹	were collected	conductance values ¹	coefficient (slope)	constant (y-intercept)	coefficient (r^2)	error of estimate	Linear-regression equation
G2	06220800	22	1986-90	146-453	0.579	4.53	0.949	13.6	DS = 0.579 * SC + 4.53
G16	06225500	17	1987-90	120-570	.614	-2.17	896.	15.1	DS = 0.614 * SC - 2.17
G22	06228000	276	1947-90	144-740	909.	5.07	.920	21.1	DS = 0.606 * SC + 5.07
G23	06228350	107	1976-90	24-200	.409	14.5	.652	11.4	DS = 0.409 * SC + 14.5
G34	06230300	37	1960-70	264-829	.754	-82.7	896.	12.9	DS = 0.754 * SC - 82.7
G36	06231000	159	1966-90	179-2,160	.758	-67.3	786.	29.8	DS = 0.758 * SC - 67.3
G42	06233900	113	1980-90	188-1,450	.722	-38.6	996	33.2	DS = 0.722 * SC - 38.6
G44	06235000	73	1967-81	552-3,060	.753	-75.2	.978	67.1	DS = 0.753 * SC - 75.2
G45	06235500	233	1954-86	204-1,590	.730	-46.7	886.	23.2	DS = 0.730 * SC - 46.7
G48	06236100	43	1973-90	193-1,100	009.	22.3	.847	53.4	DS = 0.600 * SC + 22.3
G50	06244500	40	1969-90	2,750-5,300	.842	222	.788	302	DS = 0.842 * SC + 222
G53	06259000	428	1953-87	322-1,460	.665	-13.8	506	33.8	DS = 0.665 * SC - 13.8

Number of samples and range of specific-conductance values listed in this table may not be the same as the number of samples and range of specific-conductance values listed in appendix 2 because not all the samples listed in appendix 2 had both specific-conductance and dissolved-solids value.



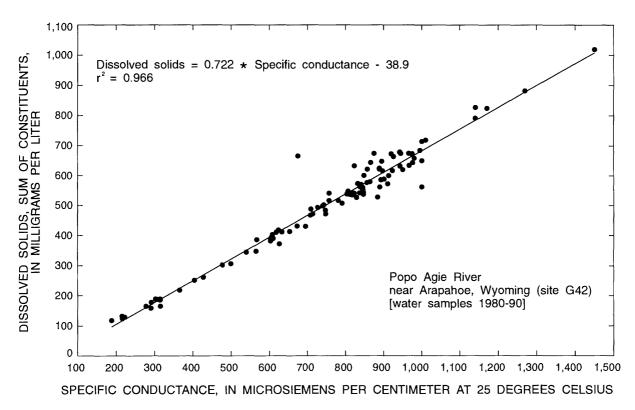


Figure 7. Relation of dissolved-solids concentration to specific conductance for water samples collected at two selected streamflow-gaging stations, Wind River Indian Reservation, Wyoming.

 Table 20.
 Number of water-quality samples in hardness, salinity-hazard, and sodium-hazard classes for selected streamflow-gaging stations on or near the Wind River Indian Reservation, Wyoming, through 1990

[Site number: site number used in this report. Hardness, salinity-hazard, and sodium-hazard classes: see report text for description of different classes]

	٦	Hard number o	Hardness classes (number of samples by class	sses by class)			Salinit number	Salinity-hazard classes (number of samples by class)	asses by class)			Sodiu number	Sodium-hazard classes (number of samples by class)	asses by class)	
Site number	Total		Moder- ately		Very	Total				Very	Total				Very
(plate 4)	samples	Soft	hard	Hard	hard	samples	Low	Medium	High	high	sambles	Low	Medium	High	high
G2	26	4	5	∞	6	26	8	18	0	0	26	26	0	0	0
G16	23	4	7	7	5	29	14	15	0	0	23	23	0	0	0
G22	354	0	100	144	110	305	43	262	0	0	276	276	0	0	0
G23	116	114	2	0	0	116	116	0	0	0	114	114	0	0	0
G34	37	0	0	0	37	37	0	14	23	0	37	37	0	0	0
G36	226	0	16	14	196	171	4	45	122	0	162	191	1	0	0
G42	117	0	15	4	86	114	4	43	<i>L</i> 9	0	114	114	0	0	0
G44	112	0	0	3	109	11	0	6	61	7	73	99	7	0	0
G45	303	0	24	23	254	250	6	72	169	0	232	232	0	0	0
G48	102	0	12	10	80	92	4	72	16	0	43	43	0	0	0
G50	51	0	0	0	51	63	0	0	0	63	41	18	20	3	0
G53	469	0	1	11	391	462	0	297	165	0	458	458	0	0	0

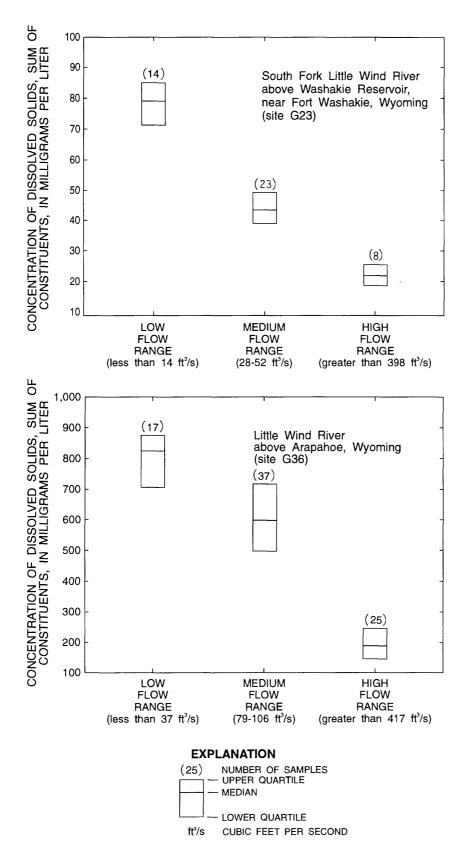


Figure 8. Lower quartile, median, and upper quartile concentrations of dissolved solids in water samples collected at different flow ranges at two selected streamflow-gaging stations for period of record through 1990, Wind River Indian Reservation, Wyoming.

Chemical Quality in Relation to Geographic Location and Geology

The chemical-quality characteristics of the streams on or near the reservation were evaluated and summarized by dividing the 12 streamflow-gaging stations into three general groups on the basis of geographic location and geologic factors. The quantity and type of soluble minerals from geologic deposits and bedrock transported into streams are the most important geologic factors related to the chemical quality of streams.

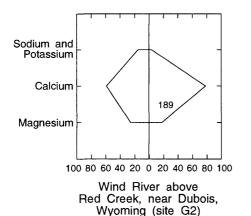
The first group consists of the following five streamflow-gaging stations located on the Wind River: Wind River above Red Creek, near Dubois (site G2), Wind River near Crowheart (site G16), Wind River at Riverton (site G22), Wind River above Boysen Reservoir, near Shoshoni (site G48), and Wind River below Boysen Reservoir (site G53). The downstream changes in mean dissolved-solids concentrations and mean ionic compositions of water samples collected at these five selected gaging stations on the Wind River are shown in figure 9.

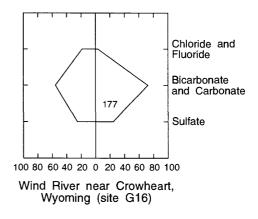
Wind River above Red Creek, near Dubois (site G2) and Wind River near Crowheart (site G16) are on the upper reaches of the Wind River (pl. 4). Most of the streamflow at these two sites come from mountainous areas that consist primarily of volcaniclastic and Precambrian rocks. These two geologic units typically contain minimal amounts of soluble minerals. Mean dissolved-solids concentrations of water samples collected at site G2 was 189 mg/L and at site G16 was 177 mg/L (fig. 9). Ionic compositions of the water samples at these two sites are dominated by calcium and bicarbonate ions. Salinity-hazard class was low or medium and sodium-hazard class was low for all samples from these two sites (table 20).

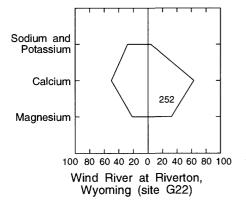
Wind River at Riverton (site G22), the next downstream station on the Wind River, is about 40 mi downstream from Wind River near Crowheart (site G16) and 1.5 mi upstream from the confluence with the Little Wind River (pl. 4). Flood-plain alluvium underlain by the Wind River Formation and outcrops of the Wind River Formation are the major geologic units in contact with surface water between sites G16 and G22. The major tributaries entering the Wind River between sites G16 and G22 are streams draining the east flank of the Wind River Range. The amount of dissolved solids in these streams is usually low, as described later in this report. The mean dissolved-solids concentration of water samples collected at site G22 was 252 mg/L (fig. 9). Ionic compositions of water samples were characterized by a mixture of calcium and sodium cations with a dominance of bicarbonate anions. Salinity-hazard class was low or medium for all samples. Sodium-hazard class was low for all samples (table 20).

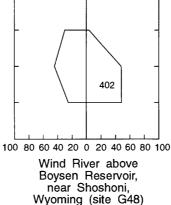
Wind River above Boysen Reservoir, near Shoshoni (site G48), the next downstream station on the Wind River, is about 12 mi downstream from the confluence of the Wind River and Little Wind River and about 5 mi upstream from Boysen Reservoir (pl. 4). The mean dissolved-solids concentration of water samples collected at site G48 was 402 mg/L (fig. 9). Ionic compositions of water samples from this site were characterized by a mixture of calcium, sodium, and magnesium cations, and sulfate and bicarbonate anions. Salinity-hazard class was medium for 72 of 92 samples, and sodium-hazard class was low for all samples from this site (table 20). Changes in the chemical quality of water samples collected at this site, when compared to the upstream sites on the Wind River, can probably be attributed mostly to the chemical quality of the Little Wind River, which enters the Wind River upstream of site G48.

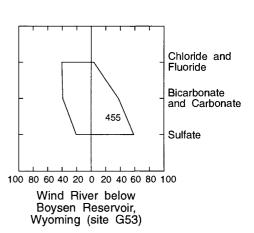
Wind River below Boysen Reservoir (site G53), the next downstream station on the Wind River, is near the outlet of Boysen Reservoir (pl. 4). The mean dissolved-solids concentration of water samples collected at site G53 was 455 mg/L (fig. 9). Ionic compositions of water samples from this site were characterized by a mixture of sodium and calcium cations with a dominance of sulfate anions. Salinity-hazard class was medium or high and sodium-hazard class was low for all samples from this site (table 20). The chemical quality of water flowing out of Boysen Reservoir is affected by the chemical quality of the Wind River, by the residence time of water in the reservoir, by the chemical quality of irrigation return flow from the Riverton Reclamation Withdrawal Area, and by the chemical quality of other streams flowing into the reservoir.



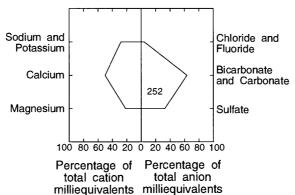








EXPLANATION



[Number inside Stiff diagram is mean concentration of dissolved solids, sum of constituents in milligrams per liter]

Figure 9. Stiff diagrams of the mean concentration of chemical analyses of water samples for period of record through 1990 at five selected streamflow-gaging stations on the Wind River, Wyoming.

The second group consists of four selected streamflow-gaging stations located on the Little Wind River or Popo Agie River. These four gaging stations are—South Fork Little Wind River above Washakie Reservoir, near Fort Washakie (site G23), Little Wind River above Arapahoe (site G36), Popo Agie River near Arapahoe (site G42), and Little Wind River near Riverton (site G45).

South Fork Little Wind River above Washakie Reservoir, near Fort Washakie (site G23) is near the base of the east flank of the Wind River Range and upstream from Washakie Reservoir (pl. 4). Streamflow at site G23 comes from mountainous areas composed primarily of Paleozoic and Precambrian rocks, which contain minimal amounts of soluble minerals. The mean dissolved-solids concentration of water samples collected at site G23 was very low (46 mg/L). Ionic compositions of water samples from this site were dominated by calcium and bicarbonate ions. Salinity-hazard class and sodium-hazard class was low for all samples from this site (table 20). The chemical quality of water samples collected from this site probably is representative of most major streams flowing out of the east flank of the Wind River Range. Surface-water quality of some of the major streams flowing out of the east flank of the Wind River Range is described by Hembree and Rainwater (1961).

Little Wind River above Arapahoe (site G36) is about 0.5 mi upstream from the confluence with the Popo Agie River (pl. 4). Most fluvial-channel deposits and flood-plain alluvium upstream from this site are underlain by the Cody Shale and Frontier Formation. These two geologic units are composed of marine deposits that contain large quantities of soluble minerals. The mean dissolved-solids concentration of water samples collected at site G36 was 612 mg/L. Ionic compositions of water samples from this site were characterized by a mixture of sodium, calcium, and magnesium cations with a dominance of sulfate anions. Salinity-hazard class was high for 122 of 171 samples and sodium-hazard class was low for 161 of 162 samples from this site (table 20). The river reach upstream from this site is probably a gaining reach for most of the year. Water samples collected from wells completed in the Little Wind River flood-plain alluvium upstream from site G36 (from Ethete to Arapahoe) had dissolved-solids concentrations generally greater than 750 mg/L and ionic compositions of mostly calcium, sodium, and sulfate ions.

Popo Agie River near Arapahoe (site G42) is about 1.2 mi upstream from the confluence with the Little Wind River (pl. 4). The mean dissolved-solids concentration of water samples collected at site G42 was 498 mg/L. Ionic compositions of water samples from this site were characterized by a mixture of calcium, magnesium, and sodium cations with a dominance of sulfate anions. Salinity-hazard class was high for 67 of 114 samples, and sodium-hazard class was low for all 114 samples from this site (table 20). The geologic and ground-water conditions upstream from this site are similar to those conditions described for Little Wind River above Arapahoe (site G36).

Little Wind River near Riverton (site G45) is about 7 mi downstream from the confluence with the Popo Agie River and about 1.5 mi upstream from the confluence with the Wind River (pl. 4). Streamflow at site G45 comes primarily from the Little Wind River and Popo Agie River but also a small amount of streamflow comes from Beaver Creek. The mean dissolved-solids concentration of water samples collected at site G45 was 554 mg/L. Ionic compositions of water samples from this site were characterized by a mixture of calcium, magnesium, and sodium cations with a dominance of sulfate anions. Salinity-hazard class was high for 169 of 250 samples and sodium-hazard class was low for all 232 samples from this site (table 20).

The third group consists of three selected streamflow-gaging stations—Ray Lake outlet near Fort Washakie (site G34), Beaver Creek near Arapahoe (site G44), and Fivemile Creek above Wyoming Canal, near Pavillion (site G50). These gaging stations are not located on any of the major streams on the reservation. Site G34 is at the outlet of Ray Lake (pl. 4), an off-channel storage reservoir used for irrigation. Typically, this reservoir is filled in May or June and partly drained during August and September. The water source for this lake is an irrigation canal called 37-C lateral. 37-C lateral is one of the main lateral canals of Ray Canal, which gets its water from the South Fork Little Wind River (pl. 4). Ray Lake is located on outcrops of the Cody Shale and the Frontier Formation. The mean dissolved-solids concentration of water samples collected at site G34 was 522 mg/L. Ionic compositions of water samples from this site were characterized by a mixture of sodium, calcium, and magnesium cations with a dominance of sulfate anions. Salinity-hazard class was medium or high and sodium-hazard class was low for all samples from this site (table 20).

Beaver Creek near Arapahoe (site G44) and Fivemile Creek above Wyoming Canal, near Pavillion (site G50) are located on intermittent streams. Site G44 is located on Beaver Creek about 0.7 mi upstream from the confluence with the Little Wind River. Site G50 is located on Fivemile Creek upstream from the Wyoming Canal (pl. 4). Chemical-quality conditions at sites G44 and G50 are affected substantially by streamflow and geologic factors. As both sites are on intermittent streams, streamflows can vary from no-flow to large floods caused primarily by heavy rainfall. Most drainage areas upstream from these two sites are in foothill or lowland areas that have surficial deposits containing large quantities of soluble minerals. The mean dissolved-solids concentration of water samples collected at site G44 was 1,170 mg/L. Ionic compositions of water samples from this site were characterized by a mixture of calcium and sodium cations with a dominance of sulfate anions. Salinity-hazard class was high for 61 of 77 samples and sodium-hazard class was low or medium for all samples from this site (table 20). The mean dissolved-solids concentration of water samples collected at site G50 was 3,460 mg/L. Ionic compositions of water samples collected at this site were characterized by a mixture of sodium and calcium cations with a dominance of sulfate anions. Salinity-hazard class was very high for all 63 samples and sodium-hazard class was low or medium for 38 of 41 samples from these sites (table 20).

In summary, most perennial streams in or near the mountainous areas have the following chemical-quality characteristics: (1) dissolved-solids concentrations are less than 200 mg/L; (2) low or medium salinity-hazard classes and low sodium-hazard class; and (3) ionic composition dominated by calcium and bicarbonate ions. With increasing distance from the mountains, most perennial streams have the following chemical-quality characteristics: (1) dissolved-solids concentrations range from about 400 to about 600 mg/L; (2) medium or high salinity-hazard classes and low sodium-hazard class; and (3) ionic composition of mostly calcium and sodium cations and sulfate anions. Intermittent streams have the following chemical-quality characteristics: (1) dissolved-solid concentrations varied from about 1,100 to about 3,500 mg/L; (2) mostly high to very high salinity-hazard classes and low or medium sodium-hazard classes; and (3) ionic composition of sodium and calcium cations with a dominance of sulfate anions.

The surface-water quality of the Owl Creek drainage basin (includes area outside the reservation) was evaluated and characterized by Ogle (1992). For assessing the surface-water quality, Ogle separated the basin into three segments (upper, middle, lower) on the basis of dissolved-solids concentration, water type, and the relation of dissolved-solids concentration to specific conductance. In summary, a downgradient increase in dissolved-solids concentration was determined in the major streams in the Owl Creek drainage basin (Ogle, 1992, p. 9-29).

Nitrates

Nitrate analyses of water samples from streamflow-gaging stations (table 17) and miscellaneous surfacewater sites (table 7) were evaluated to determine if any samples exceeded the MCL for nitrate as N (10 mg/L). For evaluating the nitrate data from surface-water sites, analyses for nitrite plus nitrate as N were grouped with analyses for nitrate as N. No water samples collected from 24 miscellaneous surface-water sites and from 27 gaging stations exceeded the MCL for nitrate as N. The highest nitrate concentration was 2.3 mg/L in a water sample collected at Wind River below Boysen Reservoir (site G53).

Trace Elements

Trace-element analyses of water samples collected from streamflow-gaging stations (table 17) and miscellaneous surface-water sites (table 7) were evaluated to determine if any sample analyses exceeded MCLs for the following constituents: arsenic, barium, cadmium, chromium, mercury, and selenium (table 9). Boron analyses were evaluated to determine if any sample analyses exceeded the State of Wyoming water-quality standards for agricultural and livestock use of water (table 10).

Arsenic—None of the 128 samples analyzed for arsenic from 12 gaging stations exceeded the MCL for arsenic (0.05 mg/L). The highest arsenic concentration was 0.004 mg/L in a water sample collected at Wind River below Boysen Reservoir (site G53).

<u>Barium</u>—None of the 121 samples analyzed for barium from 11 gaging stations exceeded the MCL for barium (1 mg/L). The highest barium concentration was 0.2 mg/L in a water sample collected at Wind River below Boysen Reservoir (site G53).

<u>Boron</u>—One of 954 samples analyzed for boron from 13 miscellaneous surface-water sites and 13 gaging stations exceeded the State of Wyoming agricultural use water-quality standard for boron (0.75 mg/L). This water sample was collected at Fivemile Creek above Wyoming Canal, near Pavillion (site G50) and had a boron concentration of 0.81 mg/L. For the miscellaneous surface-water sites, the highest boron concentration was 0.41 mg/L in a water sample collected at Alkali Lake outlet above Trout Creek 'B' Canal, near Wind River (M12).

<u>Cadmium</u>—None of the 129 samples analyzed for cadmium from 11 gaging stations exceeded the MCL for cadmium (0.01 mg/L). The highest cadmium concentration was 0.003 mg/L in a water sample collected at Wind River below Boysen Reservoir (site G53).

<u>Chromium</u>—None of the 129 samples analyzed for chromium from 12 gaging stations exceeded the MCL for chromium (0.05 mg/L). The highest chromium concentration was 0.02 mg/L in a water sample collected at Wind River below Boysen Reservoir (site G53).

Mercury—Three of 124 samples analyzed for mercury from 13 gaging stations exceeded the MCL for mercury (0.002 mg/L). These three water samples were collected at Wind River below Boysen Reservoir (site G53) and had mercury concentrations of 0.009, 0.005, and 0.003 mg/L. The reported high concentrations of mercury in surface-water samples should be considered a preliminary value and be regarded with caution unless confirmed by additional sampling and analysis.

Selenium—None of the 228 samples analyzed for selenium from 11 miscellaneous surface-water sites and 17 gaging stations exceeded the MCL for selenium (0.01 mg/L). The highest selenium concentration in the water samples collected at the 17 gaging stations was 0.002 mg/L at Wind River below Boysen Reservoir (site G53). Three water samples collected in June 1990 at three miscellaneous surface-water sites had selenium concentrations equal to or greater than 0.004 mg/L. Selenium concentrations for these three samples were 0.005 mg/L at McCaskey Drain above Coolidge Canal, near Wind River (site M11), 0.004 mg/L at Sharp Nose Drain above Little Wind River, near Arapahoe (site M15), and 0.004 mg/L at Lower Hansen Drain above Little Wind River, near Ethete (site M18). These three sites are on major drainage ditches in the Mill Creek drainage basin. Most of the area irrigated in the Mill Creek drainage basin is underlain by the Cody Shale and Frontier Formation. Ten water samples collected in 1988 from nine surface-water sites on the Riverton Reclamation Withdrawal Area (outside but near the study area) had selenium concentrations that were equal to or exceeded 0.004 mg/L (Peterson and others, 1991, p. 19).

Radiochemicals

Radiochemical analyses of water samples from streamflow-gaging stations (table 17) and miscellaneous surface-water sites (table 7) were evaluated to determine if any sample analyses exceeded the 5.0 pCi/L MCL for radium 226 and 228. None of the 128 samples collected from nine gaging stations and analyzed for radium 226 had concentrations higher than 5.0 pCi/L. Concentrations of radium 228 were not determined for any of the 128 samples. The highest radium 226 concentration was 1.6 pCi/L from a water sample collected at Beaver Creek near Arapahoe (site G44). Chemical analyses for natural uranium were evaluated to determine if any sample analyses exceeded the Suggested No-Adverse Response Level for uranium (0.035 mg/L) recommended by the National Academy of Sciences (1983). None of the 130 samples analyzed for uranium from 9 gaging

stations exceeded the Suggested No-Adverse Response Level for uranium. The highest uranium concentration was 0.022 mg/L from a water sample collected at Wind River at Riverton (site G22). Several water samples collected from surface-water sites on the Riverton Reclamation Withdrawal Area had uranium concentrations exceeding the Suggested No-Adverse Response Level (Peterson and others, 1991, p. 20).

Pesticides

Pesticide analyses of water samples collected from surface-water sites were evaluated to determine if any samples had concentrations exceeding the reporting limits for the following herbicides: 2,4-D, 2,4,5-T, dicamba, picloram, and silvex; and insecticides: diazinon, ethion, malathion, parathion, and trithion. Samples for herbicide analyses were collected at 10 streamflow-gaging stations (table 17) and 1 miscellaneous surface-water site (table 7). The herbicide 2,4-D was detected in 61 of 125 water samples collected at Wind River above Red Creek, near Dubois (site G2), Wind River near Crowheart (site G16), Little Wind River above Arapahoe (site G36), Popo Agie River at Hudson Siding, near Lander (site G39), Popo Agie River near Arapahoe (site G42), Wind River above Boysen Reservoir, near Shoshoni (site G48), Wind River below Boysen Reservoir (site G53), and Lower Hansen Drain above Little Wind River, near Ethete (site M18). The highest 2,4-D concentration was 0.001 mg/L in a water sample collected at site M18. The next highest 2,4-D concentration was 0.00032 mg/L in a water sample collected at site G42. Dicamba was detected in 45 of 83 samples collected at sites G39, G42, and G48. The highest dicamba concentration was 0.00032 mg/L in a water sample collected at site G42. Detectable concentrations of 2,4-D and dicamba did not exceed the U.S. Environmental Protection Agency (1989) applicable lifetime human-health levels, which are 70 µg/L (0.07 mg/L) for 2,4-D and 200 µg/L (0.2 mg/L) for dicamba. Picloram was detected in 52 of 84 samples collected at sites G39, G42, G48, and M18. The highest picloram concentration was 0.00015 mg/L in a water sample collected at site G42. The herbicides 2,4,5-T and silvex were not detected in any of the 130 water samples collected at selected gaging stations and miscellaneous surface-water sites. No insecticides were detected in 70 water samples collected at 7 gaging stations.

SUMMARY

Most of the reservation is in the western part of the Wind River Basin, which is a large structurally complex basin bounded on the north and southwest by upfolded and faulted mountain ranges. The main drainage area is the Wind River drainage basin, which nearly coincides with the boundary of the Wind River structural basin. Annual precipitation ranges from 6 to 8 in. in the central part of the basin to about 50 in. near the top of the Wind River Range. Rocks of all geologic periods except the Silurian are present on the reservation.

Ground water provides water for most public-supply and domestic uses and is a potential source for irrigation. On the basis of inventory data collected from nearly 1,360 wells and nearly 260 springs, hydrologic and water-quality characteristics of the water from the following 14 geologic units on the reservation were evaluated and summarized: (1) deposits of Quaternary age, which include flood-plain alluvium, slope wash and alluvium, terrace deposits, and glacial deposits; (2) volcaniclastic rocks and Wind River Formation of Tertiary age; (3) Mesozoic rocks, which include the Cody Shale, Frontier Formation, and Cloverly Formation of Cretaceous age, Nugget Sandstone of Jurassic (?) and Triassic (?) age, and the Chugwater Group of Triassic age; (4) Paleozoic rocks, which include Phosphoria Formation and related rocks of Permian age, Tensleep Sandstone of Pennsylvanian age, and Madison Limestone of Mississippian age.

Quaternary deposits provide water for domestic and public-supply uses on the reservation. Five hundred and seven wells completed in Quaternary deposits were inventoried, most of which are less than 50 ft deep. Water in these deposits in some areas is recharged seasonally by irrigation water. Water levels in some areas remain high (less than 5 ft below land surface) throughout the year. The altitude and configuration of the water

table in Quaternary deposits in the Little Wind River drainage basin indicates that the Little Wind River is a gaining stream. Median yields for different Quaternary geologic units ranged from 6 gal/min for the slope wash and alluvium to 15 to 20 gal/min for some other Quaternary geologic units. Median specific capacities ranged from 3.0 (gal/min)/ft for the flood-plain alluvium to 4.3 (gal/min)/ft for the slope wash and alluvium.

The Tertiary Wind River Formation is the major source of drinking water for domestic and public-supply uses on the reservation. Six hundred and eight wells were inventoried in this geologic unit, with depths ranging from 37 to 994 ft, and a median depth of 190 ft. Most of the wells are completed in mostly permeable, lenticular, and discontinuous sandstone deposits. Yields ranged from 0.1 to 350 gal/min, with a median value of 20 gal/min. Specific capacities ranged from 0.04 to 23 (gal/min)/ft, with a median value of 0.4 (gal/min)/ft.

One hundred and thirteen wells completed in five Mesozoic and three Paleozoic geologic units on the reservation were inventoried. Most of these wells are located near outcrops of these units. Most of the wells completed in the Mesozoic units are less than 150 ft deep, and median yields ranged from 5 gal/min for the Cody Shale to 55 gal/min for the Nugget Sandstone. Water-yield data for the Paleozoic Tensleep Sandstone and Madison Limestone are limited, but these two units are potentially the most productive, with estimated yields of as much as 1,000 gal/min.

Streams provide most of the water for irrigation, which is the largest water use on the reservation. About 100 streams, with a combined total length of about 1,100 mi., flow on the reservation. Streams originating in the mountains usually have perennial flows, and streams originating in the foothills or plains usually have ephemeral or intermittent flows. The Wind River is the main stream draining the reservation, and streamflow in this river and many of its major tributaries is affected and regulated by irrigation diversions and storage structures.

Sixty active or inactive U.S. Geological Survey streamflow-gaging stations are located on perennial, intermittent, and ephemeral streams on or near the reservation. Streamflow data collected from 24 gaging stations with 10 or more years of daily discharge records were evaluated and summarized to provide a representative, long-term overview of the streamflow characteristics of the streams on the reservation. Statistical summaries of streamflow data for these 24 gaging stations indicate low-flow, high-flow, and flow-duration characteristics of streams on the reservation are extremely variable. The largest mean monthly discharges on perennial streams are generally in June, with values ranging from 25.9 to 42.1 percent of the mean annual discharge. The smallest mean monthly discharges are generally in January or February, with values ranging from 0.2 to 3.3 percent of the mean annual discharge. Average annual runoff ranged from about 122 to 1,150 acre-ft/mi² for 21 gaging stations on mostly unregulated perennial streams to about 3.5 to 14 acre-ft/mi² for 3 gaging stations on intermittent streams.

Chemical analyses of about 300 ground-water samples collected from selected wells and springs, and about 450 specific-conductance measurements in water samples collected from selected wells and springs were evaluated. The chemical-quality characteristics of selected geologic units on the reservation were determined from these analyses and measurements.

Chemical quality of water in the Little Wind River and Popo Agie River flood-plain alluvium changes with increasing distance from the mountains. Water in the upper sections of the Little Wind River and Popo Agie River flood-plain alluvium located near the mountains, typically had dissolved-solids concentrations generally less than 400 mg/L and ionic compositions were dominated by calcium and bicarbonate ions. With increasing distance from the mountains, water in the lower sections of Little Wind River and Popo Agie River flood-plain alluvium had dissolved-solids concentrations ranging from about 600 to about 750 mg/L and ionic compositions consisting of a mixture of calcium, magnesium and sodium cations and mostly sulfate anions. The chemical-quality changes, with increasing distance from the mountains, could be caused by lithologic changes in flood-plain alluvium, the downgradient increase in recharge from irrigation return flow, or increased contact time of water with or seepage of water from the underlying Cody Shale and Frontier Formation, both of which contain substantial amounts of soluble minerals.

Water quality is variable in the Wind River Formation because this unit has highly variable lithology, permeability, and recharge conditions. Dissolved-solids concentrations in water samples from this formation ranged from 211 to 5,110 mg/L, with a median value of 490 mg/L. Ionic compositions varied from water with mixed calcium and sodium cations and dominant bicarbonate anions to water dominated by sodium and sulfate ions. Water samples from this geologic unit had variable hardness classes (soft to very hard), salinity-hazard classes of medium and hard, and variable sodium-hazard classes (low to very high).

Water samples collected from Mesozoic geologic units had median values of dissolved-solids concentrations ranging from 800 to 2,540 mg/L. Ionic compositions, hardness classes, salinity-hazard classes, and sodium-hazard classes for water samples from these geologic units were variable.

Water samples collected from five wells completed in the Paleozoic Tensleep Sandstone and Madison Limestone had dissolved-solids concentrations generally less than 250 mg/L and ionic compositions of predominately calcium and bicarbonate ions.

Linear-regression analysis was used to evaluate dissolved-solids concentration in relation to specific conductance for water samples collected from eight different geologic units. Except for water samples from one geologic unit (Chugwater Group), the squared correlation coefficient (r^2) values ranged from 0.965 to 0.988 for the other seven geologic units, which include Quaternary deposits, Wind River Formation, Cody Shale, and Frontier Formation. These r^2 values indicate there is very good correlation of specific conductance to dissolved-solids concentration in water samples from these geologic units.

Water-quality samples were collected at 33 streamflow-gaging stations and 28 miscellaneous surface-water sites on or near the reservation. Statistical summaries of chemical-quality data for 12 selected gaging stations with more than 4 years or more of records indicate that chemical quality of the streams is related to changes in streamflow, geology, and downstream location. Linear-regression analyses were used to evaluate dissolved-solids concentration in relation to specific conductance of water samples collected from these 12 gaging stations. The r^2 values were greater than 0.900 for nine of these gaging stations.

Most perennial streams in or near the mountainous areas have the following chemical-quality characteristics: (1) dissolved-solids concentrations are less than 200 mg/L; (2) low or medium salinity-hazard classes and low sodium-hazard class; and (3) ionic composition dominated by calcium and bicarbonate ions. With increasing distance from the mountains, most perennial streams have the following chemical-quality characteristics: (1) dissolved-solids concentrations range from about 400 to about 600 mg/L; (2) medium or high salinity-hazard classes and low sodium-hazard class; and (3) ionic composition of mostly calcium and sodium cations and sulfate anions. Intermittent streams have the following chemical-quality characteristics: (1) dissolved-solid concentrations varied from about 1,100 to about 3,500 mg/L; (2) mostly high to very high salinity-hazard classes and low or medium sodium-hazard classes; and (3) ionic composition of sodium and calcium cations with a dominance of sulfate anions.

REFERENCES

- Baldes, R.J., 1981, Annual project report, Wind River Indian Reservation, Wyoming, 1980: Lander, Wyoming, U.S. Fish and Wildlife Service, Lander Assistance Office, 43 p.
- _____1986a, Wind River Indian Reservation, Wyoming, draft management plan, rivers and streams, 1986: Lander, Wyoming, U.S. Fish and Wildlife Service, Lander Assistance Office, 55 p.
- _____1986b, Wind River Indian Reservation, Wyoming, draft management plan, lowland lakes and reservoirs, 1986: Lander, Wyoming, U.S. Fish and Wildlife Service, Lander Assistance Office, 37 p.
- Bates, R.L., and Jackson, J.A., eds., 1980, Glossary of geology (second ed.): Falls Church, Virginia, American Geological Institute, 751 p.
- Berry, D.W., and Littleton, R.T., 1961, Geology and ground-water resources of the Owl Creek area, Hot Springs County, Wyoming: U.S. Geological Survey Water-Supply Paper 1519, 58 p.
- Bishop and Spurlock Consulting Engineers, 1962, Report on water resources in the Wind River Basin: Lander, Wyoming, prepared for the Wyoming Natural Resource Board, 61 p.
- Bown, T.M., 1982, Geology, paleontology, and correlation of Eocene volcaniclastic rocks, southeast Absaroka Range, Hot Springs County, Wyoming: U.S. Geological Survey Professional Paper 1201-A, 75 p.
- Breckenridge, R.M., and Hinckley, B.S., 1978, Thermal springs of Wyoming: Geological Survey of Wyoming Bulletin 60, 104 p.
- Bureau of Indian Affairs, 1971, Water resource inventory, Shoshone and Arapahoe Tribes, Wind River Indian Reservation: prepared for the Shoshone and Arapahoe Tribes by the Bureau of Indian Affairs, Wind River Agency, Fort Washakie, Wyoming, no pagination.
- Bureau of Reclamation, 1966, Report on Wind Division, Wyoming-Missouri River basin project: Billings, Montana, U.S. Bureau of Reclamation Region 6, 75 p.
- 1981, Wind River Basin water supply study, Wyoming: Billings, Montana, U.S. Bureau of Reclamation Field Planning Branch, 85 p.
- Colby, B.R., Hembree, C.H., and Rainwater, F.H., 1956, Sedimentation and chemical quality of surface waters in the Wind River Basin, Wyoming: U.S. Geological Survey Water-Supply Paper 1373, 336 p.
- Cooley, M.E., 1986, Artesian pressures and water quality in Paleozoic aquifers in the Ten Sleep area of the Bighorn Basin, north-central Wyoming: U.S. Geological Survey Water-Supply Paper 2289, 54 p.
- Daddow, R.L., 1992, Ground-water and water-quality data through 1991 for selected wells and springs on the Wind River Indian Reservation, Wyoming: U.S. Geological Survey Open-File Report 92-455, 128 p.
- Druse, S.A., Lowham, H.W., Cooley, M.E., and Wacker, A.M., 1988, Floodflow characteristics of Wyoming streams—A compilation of previous investigations: Cheyenne, Wyoming, Wyoming Highway Department report, variable pagination.
- Friedman, L.C., and Erdmann, D.E., 1982, Quality assurance practices for the chemical and biological analyses of water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A6, 181 p.
- Grasso, D.N., Jennings, M.E., and Sadler, W.J., 1995, Field screening of water quality, bottom sediment, and biota associated with irrigation drainage, Wind River Indian Reservation, Wyoming, 1992-93: U.S. Geological Survey Open-File Report 95-121, 41 p.
- Heath, R.C., 1983, Basic ground-water hydrology: U.S. Geological Survey Water-Supply Paper 2220, 84 p.
- Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.
- Hembree, C.H., and Rainwater, F.H., 1961, Chemical degradation on opposite flanks of the Wind River Range, Wyoming: U.S. Geological Survey Water-Supply Paper 1535-E, 9 p.
- HKM Associates, 1979, Surface water hydrology summary statement, Wind River Indian Reservation: Billings, Montana, no pagination.

- Hurlbut, Kersich, and McCullough Consulting Engineers, 1975, Inventory of water resources, Wind River Indian Reservation, Wyoming, phase II, needs and uses: Billings, Montana, prepared for U.S. Department of the Interior, Bureau of Indian Affairs, Billings, Montana, variable pagination.
- Keefer, W.R., 1965, Stratigraphy and geologic history of the uppermost Cretaceous, Paleocene, and lower Eocene rocks in the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-A, 77 p.
- 1970, Structural geology of the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-D, 35 p.
- 1972, Frontier, Cody, and Mesaverde Formations in the Wind River and southern Bighorn Basins, Wyoming: U.S. Geological Survey Professional Paper 495-E, 23 p.
- Keefer, W.R., and Van Lieu, J.A., 1966, Paleozoic formations in the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-B, 60 p.
- Kerr, Greg, and others, 1989, Glacial meltwater as a contribution to late summer runoff, Wind River Range, Wyoming: Proceedings, Wyoming section, American Water Resources Association, Second annual meeting, Douglas, Wyoming, October 1989, 26 p.
- Langbein, W.B. and Iseri, K.T., 1960, General introduction and hydrologic definitions: U.S. Geological Survey Water-Supply Paper 1541-A, 29 p.
- Love, J.D., and Christiansen, A.C., 1985, Geologic Map of Wyoming: U.S. Geological Survey, scale 1:500,000, 3 sheets.
- Love, J.D., Christiansen, A.C., and Ver Ploeg, A.J., 1993, Stratigraphic chart showing phanerozoic nomenculture for the State of Wyoming, The Geological Survey of Wyoming, Map Series 41, 1 sheet.
- Lowham, H.W., 1988, Streamflows in Wyoming: U.S. Geological Survey Water-Resources Investigations Report 88-4045, 78 p.
- Lowry, M.E., Lowham, H.W., and Lines, G.C., 1976, Water resources of the Bighorn Basin, northwestern Wyoming: U.S. Geological Survey Hydrologic Investigations Atlas HA-512, 2 sheets.
- Maddy, D. V., Lopp, L.E., Jackson, D.L., Coupe, R.H., and Schertz, T.L., 1990, National water information user's manual, v. 2, chap. 2, water-quality system: U.S. Geological Survey Open-File Report 89-617, variable pagination.
- Martner, B.E., 1986, Wyoming climate atlas: Lincoln, Nebraska, University of Nebraska Press, 432 p.
- McGreevy, L.J., Hodson, W.G., and Rucker, S.J., IV, 1969, Ground-water resources of the Wind River Indian Reservation, Wyoming: U.S. Geological Survey Water-Supply Paper 1576-I, 145 p.
- McNeely, R.N., Neimanis, V.P., and Dwyer, L., 1979, Water quality sourcebook—A guide to water quality parameters: Ottawa, Water Quality Branch, Inland Waters Directorate, Environment Canada, 89 p.
- National Academy of Sciences and National Academy of Engineering, 1973, [1974], Water quality criteria 1972: U.S. Government Printing Office, 594 p.
- National Academy of Sciences, 1983, Drinking water and health, volume V: National Academy of Sciences Press, 157 p.
- Ogle, K.M., 1992, Surface- and ground-water quality in the Owl Creek Basin, north-central Wyoming: U.S. Geological Survey Water-Resources Investigations Report 91-4108, 65 p.
- Oltman, R.E., and Tracy, H.J., 1949, Average annual runoff in the Wind River Basin in Wyoming: U.S. Geological Survey Circular 66, 9 p.
- Owenby, J.R., and Ezell, D.S., 1992, Monthly station normals of temperature, precipitation, and heating and cooling degree days, 1961-90, Wyoming: Climatography of the United States No. 81, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina, 29 p.
- Peterson, D.A., and others, 1987, Hydrology of area 51, Northern Great Plains and Rocky Mountain Coal Provinces, Wyoming and Montana: U.S. Geological Survey Water-Resources Investigations Open-File Report 84-734, 73 p.
- Peterson, D.A., Harms, T.F., Ramirez, Pedro, Jr., Allen, G.T., and Christenson, A.H., 1991, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Riverton Reclamation Project, Wyoming, 1988-89: U.S. Geological Survey Water-Resources Investigations Report 90-4187, 84 p.

- Plafcan, Maria and Ogle, K.A., 1994, Water resources of Hot Springs County: U.S. Geological Survey Water-Resources Investigation Report 93-4141, 90 p.
- Plafcan, Maria, Eddy-Miller, C.A., Ritz, G.F., and Holland II, J.P.R., 1995, Water Resources of Fremont County, U.S. Geological Water-Resources Investigation Report 95-4095, 133 p.
- Rantz, S.E., and others, 1982, Measurements and computation of streamflow, volume 1, measurement of stage and discharge: U.S. Geological Survey Water-Supply Paper 2175, 284 p.
- Refolo, P.J., 1983, A geologic study of the Wind River Basin, Fremont and Natrona Counties, central Wyoming: Las Vegas, Nevada, CER Corporation for Gas Research Institute, 71 p.
- Richter, H.R., Jr., 1981, Volume IV-A, Occurrence and characteristics of ground water in the Wind River Basin, Wyoming: Laramie, Wyoming, University of Wyoming Water Resources Research Institute report to U.S. Environmental Protection Agency, 149 p.
- Robinove, C.J., 1958, Memorandum on artesian wells south of Riverton, Wyoming: U.S. Geological Survey Open-file Report, 7 p.
- Roncalio, Teno, 1982, Report to the District Court of the Fifth Judicial District, State of Wyoming, concerning reserved water right claims by and on behalf of the tribes of the Wind River Indian Reservation, Wyoming: Worland, Wyoming, 451 p.
- Ruby, N.K., Sagmeister, R.J., Green, S.L., and Walgren, J.D., 1991, Index of surface-water discharge, water-quality, sediment, and biological records through September 30, 1990, for Wyoming: U.S. Geological Survey Open-File Report 91-497, 46 p.
- Searcy, J.K., 1959, Flow-duration curves: U.S. Geological Survey Water-Supply Paper 1542-A, 33 p.
- Seeland, D.A., 1978, Eocene fluvial drainage patterns and their implications for uranium and hydrocarbon exploration in the Wind River Basin, Wyoming: U.S. Geological Survey Bulletin 1446, 21 p.
- Stiff, H.A., Jr., 1951, The interpretation of chemical water analysis by means of patterns: Journal of Petroleum Technology, v. 3, no. 10, sec. 1, p. 15-16; sec. 2, p. 3.
- Stoffer, P., 1985, Bibliography and index to the geology of the Wind River Basin and adjacent uplifts in the vicinity of Fremont County, Wyoming: Geological Survey of Wyoming Open-File Report 85-10, 82 p.
- U.S. Department of the Interior, 1962, Soil and range resources inventory, Wind River Indian Reservation, Wyoming: Bureau of Indian Affairs, Branch of Land Operations, 158 p.
- U.S. Environmental Protection Agency, 1989, Health advisory summaries: Washington, DC, variable pagination.
- _____1990, Drinking water regulations under the Safe Drinking Water Act: Criteria and Standards Division, Office of Drinking Water, U.S. Environmental Protection Agency, Safe Drinking Water Act Fact Sheet, May 1990, 43 p.
- U.S. Geological Survey, 1975, WATSTORE user's guide: U.S. Geological Survey Open-File Report 75-426, variable pagination.
- U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Department of Agriculture Handbook 60, 160 p.
- Wells, F.C., Gibbons, W.J., and Dorsey, M.E., 1990, Guidelines for collection and field analysis of water-quality samples from streams in Texas: U.S. Geological Survey Open-File Report 90-127, 79 p.
- Whitcomb, H.A., and Lowry, M.E., 1968, Ground-water resources and geology of the Wind River Basin area, central Wyoming: U.S. Geological Survey Hydrologic Investigations Atlas HA-270, 13 p.
- Wyoming Department of Environmental Quality, 1980, Quality standards for Wyoming groundwaters, chap. VIII in Rules and regulations, Wyoming Department of Environmental Quality, Water Quality Division: Cheyenne, Wyoming, 13 p.

GLOSSARY

- **Alluvium** consists of clay, silt, sand, gravel, or other unconsolidated material deposited by a stream or other body of running water as a sediment in the bed of a stream or on a floodplain or delta, or as a fan at the base of a mountain.
- Anticline is an arched fold in which the rock layers dip away from the axis of the fold.
- **Aquifer** is a body of rock that contains sufficient saturated, permeable material to yield substantial quantities of water to wells and springs.
- **Bedrock** is a general term for the consolidated (solid) rock that underlies soil or other unconsolidated surficial material.
- Clastic rocks are composed principally of broken rock fragments that are derived from pre-existing rocks or minerals and have been transported from their place of origin. The most common clastic rocks are sandstone and shale.
- **Colluvial deposit** is heterogeneous incoherent soil or rock material that slowly moves (creeps) downslope. Although creep is too slow to be observed, the cumulative results become obvious over a period of years.
- **Confined aquifer** is bounded above and below by impermeable beds or by beds of distinctly lower permeability than that of the aquifer itself. It is an aquifer containing confined ground water.
- Cubic foot per second (ft3/s) is the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and is equivalent to about 7.48 gallons per second, 448.8 gallons per minute, or 0.02832 cubic meter per second.
- **Discharge** is the volume of water (or generally, the volume of liquid plus suspended material) that passes a given point within a given period. Discharge also is called flow.
- **Dissolved** refers to a substance present in true chemical solution. In practice, however, the term includes all forms of substances that will pass through a 0.45-micrometer membrane filter, and thus may include some very small (colloidal) suspended particles.
- **Domestic water use** is water for household purposes, such as drinking, preparing food, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. This water use is also called residential water use.
- **Drainage basin** is the total area drained by a stream and its tributaries. The area of a drainage basin is called drainage area and usually is determined planimetrically from topographic maps.
- **Ephemeral stream** is a stream or reach of a stream that flows briefly only in direct response to precipitation in the immediate locality and whose channel is at all times above the water table.
- **Fault** is a fracture in bedrock along which movement of the bedrock has occurred.
- **Flood plain** is the lowland that borders a river, usually dry but subject to flooding when the stream overflows its banks.
- **Formation** is a body of rock identified by unique physical characteristics and relative position.
- Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.
- **Industrial water use** is water used for industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining.
- **Infiltration** is the flow of water into soil at land surface, as contrasted with percolation, which is movement of water through soil layers or other surficial material.
- **Intermittent stream** is a stream or reach of a stream that flows only certain times of the year when it receives water from springs or from some surface source such as melting snow.
- **Irrigation water use** is the artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands, such as parks and golf courses.
- **Limestone** is dense rock formed by chemical precipitation of calcium carbonate from solution in water.
- **Livestock water use** is water for livestock watering, feed lots, dairy operations, fish farming, and other on-farm needs. Livestock as used here includes cattle, sheep, goats, hogs, poultry, and other animal specialties.

Micrograms per liter (μg/L) is a unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter.

Milliequivalent is a term used primarily for comparative purposes when describing or evaluating different chemical analyses. The concept of milliequivalent can be introduced by taking into account the ionic charge of a chemical species (ion) such as calcium which has a positive two charge or sulfate which has a minus two charge. If the formula weight of a species is divided by its charge, the result is termed the "equivalent weight." When a concentration value in milligrams per liter is divided by the equivalent weight of a species, the result is "milligram-equivalents per liter." Typically, the term milligram equivalents is shortened and called "milliequivalents" (Hem, 1989, p. 56).

Milligrams per liter (mg/L) is a unit expressing the concentration of chemical constituents in solution as mass (milligrams) of solute per unit volume (liter) of water. Concentration of suspended sediment also is expressed in milligrams per liter and is based on the mass (dry weight) of sediment per liter of water-sediment mixture.

Particle size is the diameter, in millimeters, of any given sediment particle. (See particle-size classification.)

Particle-size classification used by the U.S. Geological Survey:

Classification	<u>Dimension limits, in millimeters</u>
Clay	0.00024-0.004
Silt	.004062
Sand	.062-2.00
Gravel	2.00-64.0

Peak discharge (peak flow, flood peak) is the maximum instantaneous discharge during a specified time interval. The series of annual peak discharges at a gaging station is used to determine the recurrence interval (frequency) and exceedance probability of floods.

Perennial stream is a stream that flows continuously.

Permeability is a measure of the relative ease with which a porous or fractured medium can transmit a liquid under a potential gradient (the capacity of a rock to transmit a fluid such as water or petroleum).

pH is measure of the acidity or alkalinity of water. It is defined as the negative logarithm of the hydrogen-ion concentration. This property is dimensionless and generally has a range from 0 to 14, with a pH of 7 representing neutral water. A pH of greater than 7 indicates the water is alkaline, whereas a pH value less than 7 indicates an acidic water.

Porosity is the property of a rock or soil that refers to the voids that the material contains. It may be expressed quantitatively as the ratio of the volume of voids to total volume of the material.

Potentiometric surface is a surface that is defined by the levels to which water will rise in tightly cased wells.

Public-supply water use is water withdrawn by public and private water suppliers and delivered to users. Public suppliers provide water for a variety of uses, such as domestic, commercial, thermoelectric power, industrial, and public water use.

Recharge is the process by which water is absorbed and added to the saturated zone (aquifer), either directly into a body of rock or indirectly by way of an adjacent body of rock. Also, it is the quantity of water that is added to the saturated zone.

Sandstone is the consolidated equivalent of sand. (See particle-size classification.)

Saturated zone is the subsurface zone in which all openings are full of water and are under hydrostatic pressure equal to or greater than atmospheric pressure.

Sediment is unconsolidated solid material that originates mostly from disintegrated rocks and is transported by water or air. Also, it may include chemical and biochemical precipitates or decomposed organic material, such as humus.

Shale is the consolidated equivalent of clay. (See particle-size classification.)

Siltstone is the consolidated equivalent of silt. (See particle-size classification.)

Slope wash is soil and rock material that has been moved down a slope by mass wasting assisted by running water not confined to fluvial channels.

Sodium-adsorption ratio (SAR) is a measure of the sodium hazard of water. SAR is reported as a dimensionless ratio and is computed from the individual determination of sodium, calcium, and magnesium after conversion of each to milliequivalents per liter. The SAR value of water is considered along with specific conductance in determining suitability for irrigation.

Specific capacity is the yield (rate of discharge) per unit of drawdown and is determined by dividing the pumping rate at any time during a well-acceptance test by the drawdown at the same time.

Specific conductance is a measure of the ability of the water to conduct an electrical current. It is expressed in microsiemens per centimeter at 25 degrees Celsius. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids concentration of the water.

Stage is the height of a water surface above an established datum plane.

Streamflow is the discharge in a natural channel. Although the term "discharge" can be applied to a flow of a canal, the word "streamflow" is used only to describe the discharge in a stream. The term "streamflow" is more general than "runoff," since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Surface water is an open body of water such as a stream or lake.

Terrace is a steplike landform above a stream and its floodplain, representing a former, abandoned floodplain of a stream.

Unconsolidated refers to sediment grains that are loose, separate, or unattached to one another.

Unsaturated zone is the zone between the land surface and the water table. It includes the capillary fringe. Generally, water in this zone is under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure.

Volcaniclastic refers to a clastic rock containing volcanic material.

Water table refers to the upper surface of the saturated zone where the water pressure is equal to atmospheric pressure.

Water year refers to the 12-month period from October 1 to September 30, and is designated by the calendar year in which it ends. Thus, the water year ending on September 30, 1995 is called water year 1995.

Yield is the constant or final pumping rate from a well in gallons per minute at which a well-acceptance test is conducted.

APPENDIX 1: STATISTICAL SUMMARIES OF STREAMFLOW DATA FOR SELECTED STREAMFLOW-GAGING STATIONS ON OR NEAR THE WIND RIVER INDIAN RESERVATION, WYOMING

For each streamflow-gaging station with 10 years or more of daily discharge records, on or near the Wind River Indian Reservation, the following statistical summaries are presented.

- 1. Summary of monthly and annual discharges,
- 2. magnitude and frequency of annual low flow,
- 3. magnitude and frequency of instantaneous peak flow,
- 4. magnitude and frequency of annual high flow, and
- 5. duration table of daily mean flow.

Period of record included in these statistical summaries are based on water years. For a gaging station, the period of record can vary between different statistical summaries because of the type and completeness of the discharge data available. Magnitude and frequency of instantaneous peak flow was not calculated from some gaging stations because of a lack of acceptable data.

Site G1--East Fork Wind River near Dubois, Wyoming 06220500

Summary of monthly and annual discharge 1951-57, 1976-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1952-57, 1977-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coefficient of variation	Percent- age of annual runoff
October	200	52	96	36	0.38	3.2
November	112	36	61	17	.28	2.0
December	88	29	51	15	.30	1.7
January	69	27	48	12	.24	1.6
February	67	27	47	11	.23	1.6
March	93	40	57	12	.22	1.9
April	353	64	164	81	.49	5.5
May	1,160	215	550	234	.43	18.5
June	1,760	510	1,050	408	.39	35.3
July	1,280	114	551	323	.59	18.5
August	461	51	190	100	.52	6.4
September	186	34	111	40	.37	3.7
Annual	414	126	248	77	.31	100

Period		charge, in ourrence into		ears, and n	onexceed	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%
1	30	24	21	19	16	14
3	32	26	22	20	17	15
7	34	27	24	21	19	17
14	36	29	26	23	20	18
30	40	32	28	25	22	20
60	43	35	31	29	25	24
90	45	37	33	30	27	25
120	47	39	35	32	28	26
183	58	48	43	39	35	32

Magnitude and frequency of annual high flow, based on period of record 1951-57, 1976-89

Magnitude and frequency of instantaneous peak flow, based on period of record 1952-57, 1977-89

Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)

2 50%	5	10	25	50	100
30%	20%	10%	4%	2%	1%
3,870	5,210	6,000	6,910	7,530	8,100

Weighted skew (logs) = -0.40Mean (logs) = 3.58Standard deviation (logs) = 0.16

Period		currence i	nterval, in	per second years, and n percent (exceedan	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100# 1%
1	2,250	2,990	3,430	3,940	4,290	4,610
3	1,970	2,650	3,070	3,580	3,930	4,270
7	1,660	2,310	2,720	3,230	3,590	3,950
15	1,400	1,950	2,300	2,730	3,040	3,340
30	1,120	1,570	1,860	2,210	2,470	2,720
60	885	1,210	1,400	1,620	1,770	1,910
90	716	974	1,130	1,300	1,420	1,530

Duration table of daily mean flow for period of record 1951-57, 1976-89

				Disch	arge, in cul	bic feet pe	r second, v	vhich was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99 5%	99.9%
2,080	1,100	706	466	326	173	112	82	67	58	49	40	34	30	27	24	20

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G4--Dinwoody Creek near Burris, Wyoming 06221500

Summary of monthly and annual discharge 1919-29, 1951-58 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1920-30, 1952-58

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	118	4.3	51	27	0.53	3.0
November	54	15	27	11	.39	1.6
December	38	9.1	19	7.2	.38	1.1
January	23	6.8	15	4.3	.29	.9
February	21	7.1	14	4.0	.28	.9
March	22	6.3	14	3.9	.28	.9
April	36	9.5	18	6.6	.37	1.1
May	297	11	148	76	.51	8.9
June	825	187	396	156	.39	23.8
July	902	202	516	171	.33	31.0
August	592	111	324	126	.39	19.5
September	264	14	122	83	.68	7.3
Annual	190	66	140	37	.26	100

Period		urrence int	erval, in ye	per second, ears, and no n percent (9	nexceedar	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%
1	0.00	0.00	0.00	0.61	2.3	8.2
3	.00	.00	.00	.63	2.4	8.9
7	9.3	2.1	.65	.19	.04	.01
14	9.3	3.9	2.1	1.2	.56	.32
30	11	6.7	4.7	3.4	2.2	1.6
60	13	9.7	8.3	7.2	6.1	5.5
90	14	10	8.8	7.6	6.4	5.6
120	15	11	9.6	8.3	7.0	6.2
183	22	15	13	11	8.8	7.7

Magnitude and frequency of annual high flow, based on period of record 1919-29, 1951-58

Magnitude and frequency of instantaneous peak flow, based on period of record 1920-30, 1952-58	
Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)	

2	5	10	25	50	100
50%	20%	10%	4%	2%	1%

Weighted skew (logs) = 0.04(logs) = 3.00Mean (logs) = 0.10Standard deviation

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50# 2%	100# 1%				
1	912	1,140	1,290	1,500	1,650	1,800				
3	842	1,040	1,180	1,360	1,500	1,640				
7	750	921	1,040	1,200	1,320	1,440				
15	665	813	906	1,020	1,100	1,180				
30	600	741	813	886	930	968				
60	506	615	666	714	742	764				
90	438	530	573	614	637	655				

Duration table of daily mean flow for period of record 1919-29, 1951-58

	Discharge, in cubic feet per second, which was exceeded for indicated percent (%) of time															
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
887	599	464	359	273	130	52	28	21	17	14	11	8.5	5,6	3.7	1.2	0.21

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G6--Dry Creek near Burris, Wyoming 06222500

Summary of monthly and annual discharge 1922-36, 1938-40, 1989 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1923-36, 1939-40

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent age of annual runoff
October	50	5.2	18	14	0.74	3.4
November	25	1.8	11	7.4	.67	2.1
December	15	.55	6.5	4.4	.67	1.2
January	10	.30	4.6	3.0	.65	.9
February	7.0	.20	3.0	2.1	.70	.6
March	10	.00	3.2	2.2	.68	.6
April	26	.88	9.0	6.3	.69	1.7
May	162	30	85	35	.41	15.8
June	343	51	188	78	.42	35.1
July	212	34	117	47	.40	21.9
August	164	19	60	31	.51	11.1
September	65	12	31	15	.50	5.7
Annual	68	20	45	13	.28	100

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and nonexceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%				
1	0.00	0.00	0.00	0.00	0.92	2.1				
3	.00	.00	.00	.00	.92	2.1				
7	.00	.00	.00	.00	.92	2.1				
14	.00	.00	.00	.32	.81	2.3				
30	.00	.00	.00	.90	1.3	2.3				
60	3.1	1.3	.62	.31	.12	.06				
90	3.5	1.5	.80	.43	.19	.11				
120	4.3	1.9	1.0	.59	.28	.16				
183	7.2	3.7	2.5	1.8	1.2	.88				

Magnitude and frequency of annual high flow, based on period of record 1922-36, 1938-40, 1989

Magnitude and frequency of instantaneous peak flow, based on period of
record 1923-36, 1939-40

2	5	10	25	50	100
50%	20%	10%	4%	2%	1%
418	698	905	1,190	1,410	1,640

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50# 2%	100# 1%				
1	345	519	629	760	853	941				
3	314	454	536	628	690	745				
7	270	383	449	523	571	616				
15	229	321	373	431	469	502				
30	199	270	309	349	375	397				
60	167	216	238	258	270	278				
90	141	177	192	205	211	216				

Duration table of daily mean flow for period of record 1922-36, 1938-40, 1989

				Discha	arge, in cu	bic feet pe	r second, v	vhich was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
325	199	140	98	71	44	23	13	8.5	4.9	3.4	1.8	1.3	0.47	0.23	0.08	0.02

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G8--Crow Creek near Tipperary, Wyoming 06222700

Summary of monthly and annual discharge 1963-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1964-89

Month	Maximum (ft ³ /s)	Minimum (ft³/s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent age of annual runoff
October	19	2.5	5.9	3.1	0.53	2.4
November	10	2.7	4.5	1.5	.33	1.8
December	6.4	1.6	3.5	1.2	.34	1.4
January	4.8	.62	2.8	.98	.34	1.1
February	3.9	.74	2.7	.71	.26	1.1
March	6.6	1.2	3.5	1.3	.37	1.4
April	24	2.8	9.4	5.8	.61	3.8
May	82	13	52	17	.33	20.8
June	246	23	105	57	.54	42.1
July	119	4.4	42	29	.70	16.7
August	23	2.8	12	5.7	.48	4.7
September	14	3.0	7.1	2.8	.39	2.9
Annual	41	5.6	21	7.8	.37	100

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and nonexceedance probability, in percent (%)								
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%			
1	2.0	1.3	1.0	0.74	0.50	0.37			
3	2.2	1.4	1.1	.79	.54	.40			
7	2.3	1.6	1.2	.89	.62	.48			
14	2.4	1.7	1.3	.98	.69	.53			
30	2.6	1.8	1.4	1.1	.75	.57			
60	2.8	2.0	1.5	1.2	.87	.69			
90	2.9	2.1	1.7	1.4	1.0	.85			
120	3.1	2.3	1.9	1.6	1.3	1.1			
183	3.6	2.9	2.6	2.3	2.1	2.0			

Magnitude and frequency of annual high flow, based on period of record 1963-89

Magnitude and frequency of instantaneous peak flow, based on period of
record 1964-89

Discharge	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)										
2	5	10	25	50	100						
50%	20%	10%	4%	2%	1%						
318	420	478	542	585	624						

Weighted skew (logs) = -0.48 $(\log s) = 2.49$ Mean (logs) = 0.16Standard deviation

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)										
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%					
1	201	294	341	386	411	431					
3	184	269	311	351	374	392					
7	159	237	277	317	340	359					
15	131	203	244	290	319	345					
30	113	169	201	234	255	273					
60	85	124	145	166	179	190					
90	66	94	109	123	132	139					

Duration table of daily mean flow for period of record 1963-89

				Discha	arge, in cul	oic feet pe	r second, v	vhich was	exceeded :	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
212	105	60	37	24	12	6.8	5.3	4.3	3.6	3.1	2.5	2.1	1.7	1.3	0.81	0.52

Site G10--Willow Creek near Crowheart, Wyoming 06223500

Summary of monthly and annual discharge 1922, 1926-40, 1989 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1927-40

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coefficient of variation	Percentage of annual runoff
October	18	5.1	9.4	3.6	0.38	5.0
November	13	2.5	7.5	2.8	.37	4.0
December	10	2.0	6.1	2.1	.35	3.2
January	8.0	2.0	5.1	1.5	.29	2.7
February	7.0	2.0	4.6	1.4	.31	2.4
March	8.0	2.5	4.9	1.3	.27	2.6
April	9.1	4.0	6.5	1.4	.21	3.4
May	64	6.9	28	18	.65	14.8
June	132	9.7	71	37	.52	37.4
July	55	5.7	25	14	.56	13.1
August	45	3.5	12	9.5	.77	6.6
September	22	4.7	9.3	4.3	.47	4.9

Period		currence in	cubic feet perval, in ye obability, ii	ears, and n	onexceeda	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%
1	4.1	3.1	2.7	2.3	2.0	1.7
3	4.1	3.1	2.7	2.3	2.0	1.7
7	4.1	3.2	2.7	2.3	1.9	1.7
14	4.1	3.2	2.7	2.3	1.9	1.7
30	4.2	3.2	2.7	2.3	1.9	1.7
60	4.3	3.2	2.7	2.3	1.9	1.7
90	4.6	3.4	2.9	2.4	2.0	1.7
120	4.9	3.6	3.0	2.5	2.1	1.8
183	5.8	4.4	3.8	3.3	2.8	2.6

Magnitude and frequency of instantaneous peak flow, based on period of record 1927-40

Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%) 2 10 25 50 100 50% 20% 10% 4% 2% 1% 211 403 572 1,080 1,350

Weighted skew (logs) = 0.16Mean (logs) = 2.33Standard deviation (logs) = 0.33 Magnitude and frequency of annual high flow, based on period of record 1922, 1926-40, 1989

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)										
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50# 2%	100#					
1	142	205	230	248	256	261					
3	124	189	217	242	253	261					
7	107	163	189	212	223	232					
15	92	142	167	189	201	210					
30	78	117	134	149	157	162					
60	57	83	94	103	107	110					
90	43	62	70	76	79	80					

Duration table of daily mean flow for period of record 1922, 1926-40, 1989

	Discharge, in cubic feet per second, which was exceeded for indicated percent (%) of time															
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
139	73	36	20	15	11	8.5	7.4	6.3	5.6	5.0	3.9	3.3	2.5	2.2	2.1	2.0

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G13--Bull Lake Creek above Bull Lake, Wyoming 06224000

Summary of monthly and annual discharge 1942-53, 1967-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1943-53, 1968-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	222	33	101	42	0.41	2.9
November	109	30	56	20	.36	1.6
December	62	15	38	12	.30	1.1
January	43	7.3	29	7.9	.27	.8
February	41	6.9	26	7.8	.30	.7
March	57	6.7	27	9.4	.35	.8
April	199	25	67	41	.61	1.9
May	777	170	463	158	.34	13.0
June	2,100	684	1,170	320	.27	32.8
July	1,580	385	942	292	.31	26.5
August	655	145	432	127	.29	12.2
September	533	109	204	78	.38	5.7
Annual	415	174	297	55	.19	100

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and nonexceedance probability, in percent (%)										
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%					
1	19	14	11	9.1	6.9	5.7					
3	20	15	12	9.6	7.4	6.0					
7	21	15	12	10	7.8	6.3					
14	22	16	13	11	86	7.1					
30	23	18	15	12	9.3	7.					
60	26	19	16	13	9.6	7.9					
90	28	21	17	13	10	8.1					
120	31	23	19	15	12	9.9					
183	44	35	30	27	24	22					

Magnitude and frequency of annual high flow, based on period of record 1942-53, 1967-89

Magnitude	Magnitude and frequency of instantaneous peak flow, based on period of record 1943-53, 1968-89											
Discharge		t per second, exceedance p		d recurrence i percent (%)	nterval, in							
2 50%												

3,600

3,890

4,160

3,190

Weighted skew (logs) = -0.07Mean (logs) = 3.36(logs) = 0.12Standard deviation

2,840

2,270

Period		сиггенсе і	cubic feet nterval, in obability, i	years, and	l exceedan	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%
1	2,100	2,580	2,860	3,170	3,390	3,590
3	1,940	2,370	2,610	2,890	3,080	3,250
7	1,730	2,120	2,350	2,610	2,790	2,960
15	1,500	1,870	2,090	2,340	2,520	2,680
30	1,310	1,620	1,790	1,980	2,110	2,220
60	1,100	1,320	1,440	1,560	1,640	1,710
90	920	1,090	1,170	1,250	1,310	1,350

Duration table of daily mean flow for period of record 1942-53, 1967-89

Discharge, in cubic feet per second, which was exceeded for indicated percent (%) of time																
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99 9%
2,000	1,280	940	697	525	286	143	77	50	37	29	23	20	17	14	7.2	6.4

Site G15--Bull Lake Creek near Lenore, Wyoming 06225000

Summary of monthly and annual discharge 1919-23, 1927-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1920-23, 1927-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coefficient of variation	Percent- age of annual runoff
October	782	4.2	137	138	1.0	4.2
November	467	8.3	73	71	.97	2.2
December	241	14	77	61	.79	2.3
January	267	11	97	82	.84	3.0
February	219	12	81	69	.85	2.5
March	197	.00	66	55	.84	2.0
April	601	3.6	100	113	1.1	3.1
May	831	6.0	221	179	.81	6.7
June	1,830	11	547	488	.89	16.6
July	1,650	86	825	294	.36	25.1
August	1,030	193	655	174	.27	19.9
September	982	113	408	213	.52	12.4
Annual	427	100	275	70	.25	100

Period		irrence int		ears, and r	d, for indic nonexceeds (%)	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%
1	0.00	0.00	0.73	1.8	4.0	13
3	.00	.00	.79	2.1	4.6	15
7	.00	.00	1.3	2.9	5.9	16
14	.00	.81	2.5	4.5	8.1	20
30	.00	1.6	4.2	6.9	11	25
60	31	16	12	9.0	6.6	5.4
90	39	20	15	11	8.3	6.8
120	48	25	17	13	9.6	7.8
183	69	37	27	21	15	12

Magnitude and frequency of annual high flow, based on period of record 1919-23, 1927-89

		record 1920-	23, 1927-89		
Discharge		t per second, xceedance pr			nterval, in
2	5	10	25	50	100
50%	20%	10%	4%	2%	1%

Period		currence i	nterval, in	•	l, for indic exceedan %)	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%
1	1,500	2,120	2,510	3,000	3,360	3,710
3	1,440	2,010	2,380	2,840	3,180	3,510
7	1,320	1,810	2,130	2,540	2,830	3,130
15	1,160	1,550	1,810	2,130	2,370	2,610
30	1,010	1,330	1,530	1,770	1,950	2,120
60	866	1,100	1,240	1,390	1,490	1,590
90	746	951	1,060	1,180	1,250	1,320

Duration table of daily mean flow for period of record 1919-23, 1927-89

				Discha	arge, in cul	bic feet pe	r second, v	vhich was	exceeded	for indicat	ed percent	(%) of tim	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
1,650	1,050	808	655	532	274	171	116	69	46	30	19	14	7.8	5.0	2.8	0.25

Site G16--Wind River near Crowheart, Wyoming 06225500

Summary of monthly and annual discharge 1946-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1947-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	1,420	371	690	229	0.33	4.7
November	932	298	488	120	.24	3.3
December	625	215	403	89	.22	2.8
January	560	179	387	100	.26	2.6
February	538	202	371	83	.22	2.5
March	616	226	378	83	.22	2.6
April	1,280	311	579	209	.36	4.0
May	2,940	729	1,780	571	.32	12.2
June	7,260	1,580	3,780	1,410	.37	25.9
July	5,690	1,440	2,960	1,130	.38	20.3
August	2,480	853	1,660	336	.20	11.4
September	1,720	736	1,130	242	.21	7.7
Annual	1,650	670	1,220	247	.20	100

Period	rec		erval, in ye obability, ii			ince
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100
1	258	205	181	162	142	130
3	270	214	188	169	148	136
7	285	227	200	179	157	143
14	304	242	212	189	164	149
30	329	263	231	207	180	164
60	354	283	249	221	193	175
90	367	296	262	236	208	190
120	378	309	275	249	222	205
183	447	371	335	307	278	260

Magnitude and frequency of annual high flow, based on period of record 1946-89

Magnitude and frequency of instantaneous peak flow, based on period of
record 1947-89

/ischaige	e, in cubic fee years, and e	xceedance pr			c. 741, 11
2.	5	10	25	50	100
50%	20%	10%	4%	2%	1%

Period			ice interva		nd, for indicand exceedance t (%)	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%
1	6,250	8,480	9,820	11,400	12,400	13,400
3	5,840	7,940	9,180	10,600	11,500	12,400
7	5,300	7,350	8,600	10,000	11,000	12,000
15	4,640	6,450	7,560	8,880	9,800	10,700
30	4,010	5,480	6,370	7,420	8,140	8,820
60	3,390	4,490	5,160	5,950	6,490	7,010
90	2,940	3,750	4,210	4,730	5,070	5,390

Duration table of daily mean flow for period of record 1946-89

				Discha	arge, in cub	oic feet pe	r second, v	which was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
6,760	4,120	2,860	2,220	1,840	1,340	896	599	499	439	381	315	273	239	221	197	159

Site G22--Wind River at Riverton, Wyoming 06228000

Summary of monthly and annual discharge 1913-14, 1916-17, 1919-28, 1931-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1913-14, 1916-17, 1920-28, 1931-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	1,500	183	630	262	0.42	6.2
November	895	222	447	122	.27	4.4
December	559	200	354	78	.22	3.5
January	539	151	333	93	.28	3.3
February	531	196	336	83	.25	3.3
March	650	75	348	107	.31	3.4
April	1,230	54	434	231	.53	4.3
May	4,620	73	1,310	849	.65	12.9
June	7,190	155	2,890	1,750	.60	28.6
July	5,800	39	1,820	1,360	.75	17.9
August	3,050	43	718	617	.86	7.1
September	1,790	36	505	351	.69	5.0
Annual	1,630	195	845	355	.42	100

Period				ears, and n	onexceeda	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%
1	98	41	25	16	9.3	6.4
3	112	51	32	22	13	9.4
7	131	65	43	30	19	14
14	162	85	56	39	24	17
30	217	123	83	57	35	25
60	280	180	130	94	61	44
90	318	215	158	116	7 7	56
120	340	247	192	149	106	82
183	393	289	236	195	153	128

Magnitude and frequency of annual high flow, based on period of record 1913-14, 1916-17, 1919-28, 1930-89

Magnitude and frequency of instantaneous peak flow, based on period of
record 1913-14, 1916-17, 1920-28, 1931-89

)ischarge		t per second, xceedance pr			nterval, i
2	5	10	25	50	100
50%	20%	10%	4%	2%	1%

Period		_	nce interva	-	nd, for indicand exceedance	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%
1	5,530	8,000	9,240	10,400	11,100	11,600
3	5,170	7,640	8,870	10,000	10,700	11,200
7	4,620	7,090	8,320	9,470	10,100	10,600
15	3,910	6,110	7,260	8,380	9,020	9,520
30	3,110	5,050	6,180	7,400	8,160	8,810
60	2,360	3,910	4,870	5,980	6,710	7,370
90	1,870	3,100	3,890	4,840	5,500	6,120

Duration table of daily mean flow for period of record 1913-14, 1916-17, 1919-28, 1930-89

				Discha	arge, in cub	oic feet per	r second, v	vhich was	exceeded :	for indicate	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
6,240	3,490	2,150	1,390	974	627	497	423	365	320	267	190	118	62	40	29	15

Site G23--South Fork Little Wind River above Washakie Reservoir, near Fort Washakie, Wyoming 06228350

Summary of monthly and annual discharge 1977-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1978-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	94	15	42	20	0.46	2.8
November	38	16	27	7.3	.27	1.8
December	31	12	22	5.8	.26	1.5
January	25	6.1	16	4.7	.29	1.1
February	26	6.7	14	4.7	.34	.9
March	34	9.6	17	6.0	.36	1.1
April	95	29	51	20	.39	3.4
May	403	132	247	78	.32	16.6
June	1,070	271	569	238	.42	38.1
July	549	81	326	167	.51	21.8
August	197	31	108	49	.45	7.2
September	83	20	55	16	.30	3.7
Annual	188	71	125	36	.29	100

Period		irrence int	cubic feet perval, in ye obability, ir	ars, and n	onexceeda	
(con- secutive days)	2 50%	5 20%	10 10%	20# 5%	50# 2%	100# 1%
1	11	8.6	7.8	7.1	6.5	6.1
3	11	9.0	8.1	7.4	6.6	6.2
7	11	9.2	8.3	7.6	6.9	6.5
14	12	10	9.1	8.4	7.6	7.2
30	13	11	9.9	9.4	8.8	8.5
60	14	12	11	11	10	9.9
90	15	13	12	12	11	11
120	17	15	14	13	13	12
183	23	18	16	15	13	12

Magnitude and frequency of annual high flow, based on period of record 1977-89

		record 1	1978-89		
Discharge	, in cubic fee	t per second,	for indicated	l recurrence i	nterval, ir
	years, and e	xceedance pr	obability, in	percent (%)	
2	years, and e	exceedance pr	obability, in	percent (%)	100

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	25# 4%	50# 2%	100#				
1	1,010	1,300	1,500	1,740	1,920	2,100				
3	912	1,160	1,320	1,500	1,630	1,750				
7	780	1,010	1,160	1,350	1,490	1,630				
15	688	921	1,070	1,260	1,400	1,530				
30	601	827	970	1,140	1,270	1,390				
60	481	648	745	853	926	993				
90	384	505	574	650	700	746				

Duration table of daily mean flow for period of record 1977-89

				Disch	arge, in cu	bic feet pe	r second, v	vhich was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
1,030	588	379	253	176	85	53	37	27	21	17	14	12	9.3	7.1	5.6	4.7

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G25--Little Wind River near Fort Washakie, Wyoming 06228500

Summary of monthly and annual discharge 1922-40 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1923-40

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	149	21	59	38	0.65	4.0
November	75	15	36	18	.52	2.4
December	50	12	26	12	.46	1.7
January	50	10	22	11	.49	1.5
February	40	8.0	20	9.1	.45	1.4
March	50	8.0	23	12	.53	1.5
April	95	8.7	44	25	.56	3.0
May	414	111	242	84	.35	16.5
June	880	133	511	226	.44	34.7
July	607	69	291	131	.45	19.7
August	270	52	127	56	.44	8.6
September	156	24	72	37	.51	4.9
Annual	179	59	123	34	.27	100

Period		urrence int	cubic feet perval, in ye bability, ir	ars, and n	onexceeda	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%
1	16	12	9.6	8.2	6.9	6.1
3	16	12	9.6	8.2	6.9	6.1
7	16	12	9.7	8.4	7.1	6.4
14	17	12	10	8.7	7.5	6.8
30	17	12	10	8.9	7.8	7.1
60	17	12	10	9.0	7.9	7.3
90	18	13	11	9.6	8.5	7.8
120	20	14	12	11	9.4	8.7
183	27	19	17	15	13	12

Magnitude and frequency of annual high flow, based on period of record 1922-40

Magnitude and frequency of instantaneous peak flow, based on period of
record 1923-40

Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)										
2	5	10	25	50	100					
50%	20%	10%	4%	2%	1%					

Period		charge, in ecurrence i pro	nterval, in	•	exceedan	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50# 2%	1 0 0#
1	989	1,500	1,830	2,240	2,540	2,830
3	919	1,300	1,520	1,750	1,890	2,020
7	788	1,100	1,260	1,430	1,540	1,620
15	649	900	1,040	1,180	1,270	1,350
30	547	761	883	1,020	1,100	1,180
60	442	584	654	724	764	798
90	362	466	515	563	590	611

Duration table of daily mean flow for period of record 1922-40

				Discha	arge, in cul	bic feet per	r second, v	vhich was	exceeded:	for indicat	ed percent	(%) of tin	ne			_
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
937	526	341	234	176	109	64	45	32	25	20	15	13	10	8.3	7.7	7.2

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G28--North Fork Little Wind River at Fort Washakie, Wyoming 06229000

Summary of monthly and annual discharge 1922-40 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1923-40

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coefficient of variation	Percent- age of annual runoff
October	152	17	54	40	0.73	4.0
November	85	15	37	21	.55	2.7
December	50	13	27	12	.43	1.9
January	50	10	22	10	.47	1.6
February	40	10	21	8.5	.40	1.6
March	50	10	24	10	.42	1.8
April	75	20	46	17	.36	3.3
May	473	123	250	97	.39	18.2
June	1,020	115	497	249	.50	36.2
July	569	47	246	137	.56	17.9
August	256	14	92	58	.64	6.7
September	141	22	58	37	.63	4.2
Annual	207	39	115	39	.34	100

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and nonexceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%				
1	18	13	11	10	8.6	7.8				
3	18	13	11	10	8.6	7.8				
7	18	13	11	10	8.8	7.9				
14	18	13	12	11	9.4	8.8				
30	18	13	12	11	9.6	9.0				
60	18	14	12	11	9.9	9.4				
90	20	14	13	11	10	9.5				
120	21	16	13	12	10	9.6				
183	27	19	15	13	11	10				

Magnitude and frequency of annual high flow, based on period of record 1922-40

> Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance

Magnitude and frequency of instantaneous peak flow, based on period of
record 1923-40

Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)

Weighted skew Mean Standard deviation

20%

1,710

50%

1,090

10 10%	25 4%	50 2%	100 1%
2,130	2,680	3,090	3,500
(logs) = -0.25 (logs) = 3.03 (logs) = 0.24			

probability, in percent (%) Period (con-2 5 10 25 50# 100# secutive days) 50% 20% 10% 4% 2% 1% 1 965 1,440 1,740 2,100 2,350 2,600 3 868 1,300 1,580 1,930 2,190 2,440 7 1,910 756 1,100 1,320 1,570 1,750 15 638 913 1,080 1,280 1,410 1,540 30 527 739

868

661

515

454

336

1,020

577

1,120

817

614

1,220

871

644

Duration table of daily mean flow for period of record 1922-40

60

90

				Discha	urge, in cul	bic feet pe	r second, v	vhich was	exceeded:	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
913	504	325	219	153	86	52	39	30	25	21	16	14	12	11	10	9.1

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G36--Little Wind River above Arapahoe, Wyoming 06231000

Summary of monthly and annual discharge 1980-89 $[ft^3/s, cubic feet per second]$

Magnitude and frequency of annual low flow, based on period of record 1981-89

Month	Maximum (ft ³ /s)	Minimum (ft³/s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	264	35	129	74	0.57	5.6
November	182	47	112	41	.37	4.9
December	130	51	90	23	.25	3.9
January	101	43	74	16	.21	3.2
February	102	42	77	18	23	3.3
March	142	56	97	28	.29	4.2
April	159	32	101	42	.42	4.4
May	568	30	269	182	.68	11.7
June	1,780	168	822	548	.67	35.8
July	856	26	384	276	.72	16.7
August	234	14	78	65	.84	3.4
September	125	9.6	64	39	.61	2.8
Annual	344	83	191	80	.42	100

Period			erval, in ye bability, i			
(con- secutive days)	2 50%	5 20%	10 10%	20# 5%	50# 2%	100# 1%
1	25	14	9.7	7.0	4.8	3.6
3	27	15	10	7.4	5.0	3.8
7	29	16	11	7.9	5.3	3.9
14	31	17	12	8.3	5.4	4.0
30	37	20	14	9.9	6.5	4.8
60	46	27	19	14	9.2	6.9
90	64	38	27	19	12	8.6
120	76	48	34	25	16	12
183	89	58	44	34	24	19

record 1980-89

Magnitude	and frequen	record 1		low, based or	n period of
Discharge		t per second, exceedance pr			nterval, in
2	5	10	25	50	100
50%	20%	10%	4%	2%	1%

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	25# 4%	50# 2%	100# 1%				
1	1,630	2,480	3,010	3,630	4,060	4,460				
3	1,460	2,220	2,710	3,290	3,700	4,090				
7	1,230	1,900	2,300	2,760	3,060	3,330				
15	1,030	1,650	2,040	2,520	2,850	3,160				
30	834	1,340	1,700	2,170	2,530	2,890				
60	628	1,000	1,250	1,540	1,750	1,950				
90	466	726	894	1,100	1,240	1,380				

Magnitude and frequency of annual high flow, based on period of

Duration table of daily mean flow for period of record 1980-89

				Discha	arge, in cul	oic feet per	r second, v	vhich was	exceeded :	for indicate	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
1,800	802	407	245	188	132	106	91	79	69	56	37	26	17	11	9.0	7.1

[#] Reliability of values in column is uncertain, and potential errors are large.

(Not calculated for this station)

Site G37--North Fork Popo Agie River near Milford, Wyoming 06232000

Summary of monthly and annual discharge 1946-63 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1947-63

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	74	22	40	16	0.40	2.7
November	47	15	28	9.5	.34	1.9
December	31	8.4	19	5.8	.31	1.3
January	22	7.7	16	4.5	.29	1.1
February	23	10	15	3.3	.22	1.0
March	19	9.9	14	2.3	.16	1.0
April	119	17	39	26	.67	2.7
May	514	106	274	112	.41	18.8
June	1,020	277	588	207	.35	40.4
July	599	104	274	148	.54	18.8
August	174	51	97	38	.39	6.6
September	99	31	55	21	.39	3.8
Annual	177	66	122	32	.26	100

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and nonexceedance probability, in percent (%)										
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%					
1	10	7.7	6.5	5.5	4.6	4.0					
3	11	8.0	6.8	5.8	4.8	4.1					
7	11	8.5	7.1	6.1	4.9	4.3					
14	12	9.0	7.6	6.5	5.3	4.6					
30	12	9.8	8.4	7.3	6.1	5.4					
60	13	11	9.5	8.5	7.5	6.8					
90	15	12	11	9.5	8,3	7.6					
120	16	13	11	9.8	8.5	7.7					
183	21	17	15	14	13	12					

Magnitude and frequency of annual high flow, based on period of record 1946-63

Magnitude and frequency of instantaneous peak flow, based on period of
record 1947-63

2 5 10 25 50 100 50% 20% 10% 4% 2% 1% 1,190 1,850 2,360 3,090 3,690 4,34	50% 20% 10% 4%	25	10	 		
				_		
1,190 1,830 2,300 3,090 3,090 4,34	1,190 1,630 2,300 3,090			 50% 20%		
Weighted skew (logs) = 0.21				 		

Period		scharge, in ecurrence i pro		years, and	exceedan	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50# 2%	100# 1%
I	992	1,530	1,970	2,630	3,210	3,860
3	920	1,390	1,760	2,290	2,750	3,260
7	852	1,210	1,450	1,780	2,040	2,300
15	756	1,000	1,150	1,320	1,440	1,550
30	625	823	942	1,080	1,180	1,270
60	475	615	698	792	856	916
90	379	488	549	617	662	703

Duration table of daily mean flow for period of record 1946-63

				Discha	arge, in cu	bic feet pe	r second, v	which was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
983	568	368	258	164	83	50	34	24	19	16	13	11	8.8	7.9	6.9	5.6

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G38--North Popo Agie River near Lander, Wyoming 06232500

Summary of monthly and annual discharge 1939-53 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1940-53

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent age of annual runoff
October	82	11	39	22	0.56	3.1
November	59	7.4	34	12	.36	2.6
December	38	11	27	7.1	.27	2.1
January	32	8.6	23	5.8	.25	1.8
February	31	10	21	5.3	.25	1.7
March	34	11	21	4.9	.23	1.7
April	111	14	45	25	.56	3.6
May	394	90	249	91	.37	19.6
June	748	90	492	210	.43	38.7
July	448	21	232	144	.62	18.2
August	128	6.7	55	41	.74	4.3
September	95	11	34	24	.72	2.7
Annual	155	30	106	37	.35	100

Period		charge, in our arrence into pro		ars, and n	onexceeda	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%
1	11	7.5	5.9	4.9	3.8	3.3
3	12	8.0	6.4	5.2	4.1	3.5
7	13	8.6	6.9	5.7	4.5	3.9
14	14	9.5	7.5	6.1	4.8	4.0
30	16	11	8.3	6.7	5.1	4.3
60	18	13	11	8.7	6.8	5.8
90	22	16	13	11	8.1	6.6
120	23	18	14	11	8.7	7.0
183	26	19	15	12	9.4	7.8

Magnitude and frequency of annual high flow, based on period of record 1939-53

Magnitude	e and frequen	cy of instanta record l		low, based or	n period of
Discharge	e, in cubic fee years, and e	t per second, exceedance pi			nterval, in
2	5	10	25	50	100
50%	20%	10%	4%	2%	1%

2,440

2,770

3,080

2,010

Weighted skew (logs) = -0.20Mean (logs) = 3.05Standard deviation (logs) = 0.20

1,660

1,130

Period		currence i	cubic feet nterval, in obability, i	years, and	exceedan	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50# 2%	100#
1	1,030	1,400	1,580	1,760	1,870	1,960
3	924	1,250	1,420	1,590	1,700	1,780
7	805	1,090	1,240	1,380	1,470	1,550
15	677	909	1,020	1,120	1,170	1,210
30	557	752	842	924	968	1,000
60	423	578	648	710	743	768
90	330	461	522	579	610	63:

Duration table of daily mean flow for period of record 1939-53

				Disch	arge, in cul	oic feet pe	r second, v	vhich was	exceeded :	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
938	506	321	214	129	61	40	31	27	24	21	15	11	8.0	6.8	6.2	5.3

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G40--Little Popo Agie River at Hudson, Wyoming 06233500

Summary of monthly and annual discharge 1939-53 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1940-53

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	80	18	56	18	0.32	4.9
November	69	16	50	13	.25	4.4
December	62	18	41	11	.26	3.6
January	52	14	36	10	.29	3.2
February	50	21	38	9.5	.25	3.3
March	87	32	52	13	.25	4.6
April	137	45	94	26	.28	8.3
May	425	82	236	93	.39	20.7
June	668	41	325	176	.54	28.6
July	310	11	121	90	.74	10.6
August	92	1.3	43	30	.70	3.8
September	104	6.0	44	27	.62	3.9
Annual	147	26	95	34	.36	100

Period		urrence int	erval, in y	per second ears, and n n percent (onexceeda	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100# 1%
1	13	3.5	1.4	0.59	0.19	0.09
3	15	4.1	1.7	.71	.24	.11
7	17	5.0	2.2	.96	.34	.16
14	20	6.6	3.0	1.4	.52	.25
30	23	9.1	4.6	2.4	.99	.51
60	30	14	7.6	4.1	1.8	1.0
90	35	19	12	7.9	4.4	2.8
120	38	25	18	13	8.6	6.3
183	43	29	22	17	12	9.0

Magnitude and frequency of annual high flow, based on period of record 1939-53

Discharge	•	eet per second, fo l exceedance pro			nterval, ir
2 50%	5 20%	10 10%	25 4%	50 2%	100 1%
684	935	1,110	1,340	1,520	1,710

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)								
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50# 2%	100# 1%			
1	581	871	1,050	1,270	1,420	1,570			
3	513	782	957	1,170	1,330	1,480			
7	454	701	858	1,050	1,180	1,300			
15	405	613	733	864	949	1,020			
30	351	521	619	725	793	853			
60	283	416	487	560	604	641			
90	236	338	389	438	467	489			

Duration table of daily mean flow for period of record 1939-53

				Discha	arge, in cul	bic feet pe	r second, v	vhich was	exceeded:	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99. 9 %
601	363	247	159	116	78	62	52	46	39	33	24	14	5.2	2.5	1.5	0.57

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G42--Popo Agie River near Arapahoe, Wyoming 06233900

Summary of monthly and annual discharge 1980-89 $[ft^3/s, cubic feet per second]$

Magnitude and frequency of annual low flow, based on period of record 1981-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent age of annual runoff
October	383	80	197	87	0.44	4.7
November	197	116	153	31	.20	3.7
December	165	100	128	21	.17	3.1
January	155	88	112	20	.18	2.7
February	145	84	112	22	:19	2.7
March	209	97	150	37	.25	3.6
April	470	101	246	112	.45	5.9
May	1,290	272	748	367	.49	18.0
June	2,920	404	1,340	899	.67	32.2
July	1,180	91	594	382	.64	14.3
August	298	40	183	94	.51	4.4
September	331	60	194	79	.41	4.7
Annual	566	186	347	136	.39	100

Period		urrence int	cubic feet; erval, in ye bability, in	ears, and n	onexceed	
(con- secutive days)	2 50%	5 20%	10# 10%	20# 5%	50# 2%	100# 1%
1	61	35	25	18	12	9.0
3	65	40	29	21	15	11
7	72	46	35	27	20	16
14	84	59	47	37	28	22
30	95	67	52	41	29	23
60	108	79	62	48	35	27
90	114	87	71	58	44	36
120	123	96	81	68	54	45
183	142	111	95	82	69	61

Magnitude and frequency of instantaneous peak flow, based on period of

Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)

2 5 10 25 50 100
50% 20% 10% 4% 2% 1%

(Not calculated for this station)

Discharge, in cubic feet per second, for ind	icated
recurrence interval, in years, and exceeds	ance
probability, in percent (%)	

Magnitude and frequency of annual high flow, based on period of record 1980-89

Period	probability, in percent (%)								
(con- secutive days)	2 50%	5 20%	10 10%	25# 4%	50# 2%	100# 1%			
1	2,120	3,050	3,710	4,590	5,270	5,980			
3	1,950	2,890	3,570	4,490	5,210	5,980			
7	1,740	2,650	3,290	4,130	4,780	5,440			
15	1,600	2,460	3,040	3,770	4,310	4,840			
30	1,320	2,100	2,680	3,490	4,140	4,840			
60	1,030	1,610	2,060	2,690	3,210	3,770			
90	811	1,250	1,580	2,040	2,410	2,820			

Duration table of daily mean flow for period of record 1980-89

				Discha	arge, in cul	bic feet pe	r second, v	vhich was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
2,760	1,380	830	539	385	263	199	166	144	128	112	91	77	59	43	34	24

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G45--Little Wind River near Riverton, Wyoming 06235500

Summary of monthly and annual discharge 1942-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1943-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	728	115	328	131	0.40	4.7
November	501	174	279	71	.25	4.0
December	351	129	213	42	.20	3.1
January	302	95	185	40	.22	2.7
February	728	123	212	91	.43	3.0
March	427	181	264	54	.20	3.8
April	1,040	148	372	167	.45	5.4
May	2,350	242	1,130	532	.47	16.2
June	5,110	288	2,420	1,200	.50	34.8
July	2,830	117	1,020	712	.70	14.7
August	699	58	264	149	.56	3.8
September	1,320	83	265	197	.74	3.8
Annual	1,020	236	579	194	.33	100

Period (con- secutive days)	reci		erval, in ye bability, in			ince
	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%
1	107	76	62	52	42	36
3	112	79	64	53	42	36
7	118	83	67	56	45	38
14	127	90	74	61	49	42
30	141	102	84	70	57	49
60	163	121	101	86	71	62
90	182	144	126	111	9.7	87
120	199	164	147	134	120	111
183	220	177	158	145	131	123

Magnitude and frequency of annual high flow, based on period of record 1942-89

Magnitude and frequency of instantaneous peak flow, based on period of
record 1943-89

Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)											
2	5	10	25	50	100						
50%	20%	10%	4%	2%	1%						

Period (con- secutive days)	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)										
	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%					
1	4,510	6,720	8,030	9,500	10,500	11,300					
3	4,150	6,070	7,130	8,270	8,980	9,590					
7	3,720	5,340	6,170	6,960	7,420	7,780					
15	3,200	4,570	5,250	5,880	6,240	6,510					
30	2,620	3,780	4,380	4,970	5,320	5,600					
60	1,950	2,810	3,270	3,720	3,990	4,210					
90	1,510	2,160	2,520	2,890	3,120	3,310					

Duration table of daily mean flow for period of record 1942-89

Discharge, in cubic feet per second, which was exceeded for indicated percent (%) of time																
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
4,590	2,440	1,480	915	600	395	313	267	234	206	180	147	121	91	74	62	50

Site G49--Muskrat Creek near Shoshoni, Wyoming 06239000

Summary of monthly and annual discharge 1951-58, 1960-73 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of
record 1952-58, 1961-73

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	0.10	0.00	0.00	0.02	4.7	0.0
November	.00	.00	.00.	.00		.0
December	1.0	.00	.05	.21	4.7	.1
January	.00	.00	.00	.00		.0
February	245	.00	15	54	3.7	33.7
March	7.4	.00	.39	1.6	4.0	.9
April	101	.00	5.1	21	4.2	11.8
May	151	.00	10	32	3.1	23.8
June	140	.00	10	30	2.8	24.1
July	24	.00	1.6	5.3	3.4	3,6
August	4.7	.00	.41	1.3	3.2	.9
September	3.3	.00	.45	.95	2.1	1.0
Annual	22	.00	3.5	6.1	1.7	100

Period	n		nterval, in ye robability, in			ce
(con- secutive	2	5	10	20	50	100#
days)	50%	20%	10%	5%	2%	1%

Magnitude and frequency of annual high flow, based on period of record 1951-58, 1960-73

Discharge, in cubic feet per second, for indicated

recurrence interval, in years, and exceedance probability, in percent (%) Period (con-2 5 25 50 100# secutive 10 50% 20% 10% 4% 2% 1% days) 146 636 1,250 2,410 1 3,570 5,010 3 71 336 701 1,450 2,270 3,350 7 33 165 358 777 1,930 1,260 15 16 87 197 451 759 1,210 30 9.0 48 108 246 413 655 60 5.2 26 58 127 207 319 90 3.6 18 38 84 138 214

Magnitude and frequency of instantaneous peak flow, based on period of record 1952-58, 1961-73

Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)

2 5 10 25 50 100
50% 20% 10% 4% 2% 1%

5,870

8,450

11,800

3,370

Weighted skew (logs) = 0.12Mean (logs) = 2.90Standard deviation (logs) = 0.48

2,020

781

Duration table of daily mean flow for period of record 1951-58, 1960-73

				Discha	arge, in cul	bic feet pe	r second, v	vhich was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
48	0.46	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G50--Fivemile Creek above Wyoming Canal, near Pavillion, Wyoming 06244500

Summary of monthly and annual discharge 1950-75, 1989 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1951-75

Month	Maximum (ft ³ /s)	Minimum (ft³/s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coefficient of variation	Percent- age of annual runoff
October	5.5	0.00	2.0	1.5	0.76	7.1
November	6.1	.00	2.2	1.8	.83	7.7
December	5.3	.00	1.2	1.3	1.1	4.2
January	3.3	.00	1.1	1.2	1.1	4.0
February	6.9	.00	2.5	1.9	.76	8.8
March	12	.27	4.3	2.7	.61	15.4
April	6.6	.10	3.7	1.8	.49	12.9
May	7.7	.38	3.1	1.7	.54	11.0
June	26	.04	3.7	6.0	1.6	13.2
July	12	.00	1.4	2.4	1.8	4.9
August	5.8	.00	.57	1.2	2.2	2.0
September	15	.00	2.5	3.8	1.5	8.8
Annual	5.1	.25	2.3	1.4	.61	100

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and nonexceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%				
1	0.00	0.00	0.00	0.00	0.00	0.00				
3	.00	.00	.00	.00	.00	.00				
7	.00	.00	.00	.00	.00	.00				
14	.00	.00	.00	.00	.00	.00				
30	.00	.00	.00	.00	.00	.00				
60	.00	.00	.00	.00	.00	.04				
90	.00	.00	.00	.00	.00	.15				
120	.00	.00	.00	.00	.05	.37				
183	.00	.00	.00	.04	.15	.86				

Magnitude and frequency of annual high flow, based on period of 1ecord 1950-75, 1989

Magnitude and frequency of instantaneous peak flow, based on period of
record 1951-75

Discharge	e, in cubic fee years, and e	t per second, exceedance pr			nterval, in
		10	25	50	100
2	,				

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and exceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%				
1	27	57	88	145	203	279				
3	19	36	51	77	102	131				
7	12	23	34	51	66	85				
15	8.3	15	21	30	39	48				
30	6.5	11	15	19	23	27				
60	5.1	8.5	11	13	14	16				
90	4.6	7.2	8.6	10	11	12				

Duration table of daily mean flow for period of record 1950-75, 1989

				Disch	arge, in cu	bic feet pe	r second, v	vhich was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
20	7.7	5.8	4.7	3.9	2.9	1.9	1.1	0.48	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Site G52--Muddy Creek near Pavillion, Wyoming 06257500

Summary of monthly and annual discharge 1950-53, 1955-58, 1960-64, 1966-73 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1950-53, 1956-58, 1961-64, 1967-73

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coefficient of variation	Percent- age of annual runoff
October	14	0.40	3.7	3.2	0.87	6.3
November	8.0	.25	3.3	2.3	.68	5.7
December	7.7	.00	1.9	1.8	.98	3.2
January	4.1	.00	1.4	1.4	.98	2.4
February	8.5	.00	3.4	2.3	:68	5.9
March	14	3.9	7.9	3.0	.38	13.6
April	33	2.7	8.8	6.3	.72	15.1
May	24	.98	7.7	6.4	.82	13.4
June	57	.14	9.7	14	1.5	16.7
July	18	.00	4.5	5.0	1.1	7.8
August	9.4	.00	1.9	2.3	1.2	3.2
September	21	.00	3.8	5.1	1.3	6.6
Annual	9.7	1.5	4.8	2.2	.45	100

Period	Discharge, in cubic feet per second, for indicated recurrence interval, in years, and nonexceedance probability, in percent (%)									
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50# 2%	100#				
1	0.00	0.00	0.00	0.00	0.00	0.00				
3	.00	.00	.00	.00	.00	.00				
7	.00	.00	.00	.00	.00	.00				
14	.00	.00	00	.00.	.00	.00				
30	.00	.00	.00	.00	.00	.00				
60	.00	.00	.00	.00	.00	.35				
90	.00	.00	.00	.02	.10	.70				
120	1.2	.42	.24	.14	.08	.05				
183	1.8	.76	.45	.29	.16	.11				

Magnitude and frequency of annual high flow, based on period of record 1950-53, 1955-58, 1960-64, 1966-73

Magnitude and frequency of instantaneous peak flow, based on period of record 1950-53, 1956-58, 1961-64, 1967-73

Discharge, in cubic feet per second, for indicated recurrence interval, in

2	5	10	25	50	100
50%	20%	10%	4%	2%	1%
395	985	1,550	2,480	3,330	4,310

(logs) = -0.22Mean $(\log s) = 2.58$ Standard deviation (logs) = 0.49

Period		currence i	cubic feet nterval, in obability, i	years, and	l exceedan	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100# 1%
1	87	164	230	333	424	527
3	48	86	121	180	237	307
7	29	51	74	116	161	220
15	19	33	47	73	100	138
30	14	23	32	47	64	85
60	11	17	23	31	39	48
90	9.1	14	18	24	30	36

Duration table of daily mean flow for period of record 1950-53, 1955-58, 1960-64, 1966-73

			_	Disch	arge, in cul	bic feet pe	r second, v	vhich was	exceeded:	for indicat	ed percent	(%) of tim	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
45	16	11	7.8	6.5	4.8	3.6	2.6	1.6	0.73	0.13	0.01	0.00	0.00	0.00	0.00	0.00

[#] Reliability of values in column is uncertain, and potential errors are large.

Site G53--Wind River below Boysen Reservoir, Wyoming 06259000

Summary of monthly and annual discharge 1952-89 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1953-89

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	2,850	332	1,240	554	0.45	7.3
November	2,090	306	1,250	492	.39	7.3
December	2,010	301	1,220	447	.37	7.2
January	2,210	299	1,150	447	.39	6.8
February	2,200	210	1,120	490	.44	6.6
March	2,030	213	1,170	501	.43	6.9
April	2,240	389	1,280	495	.38	7.5
May	2,360	777	1,400	422	.30	8.2
June	5,220	1,010	2,010	1,180	.59	11.8
July	8,820	1,020	2,410	1,910	.79	14.2
August	2,320	922	1,460	430	.29	8.6
September	2,500	732	1,300	386	.30	7.6
Annual	2,350	612	1,420	400	.28	100

Period		irrence int	cubic feet erval, in ye bability, i	ears, and n	onexceed	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%
1	564	231	98	39	10	3.7
3	660	296	140	63	20	8.4
7	677	458	359	287	218	178
14	738	497	385	305	227	184
30	790	548	432	346	262	214
60	890	616	480	379	280	224
90	1,010	706	544	422	304	238
120	1,100	768	588	450	317	243
183	1,200	836	641	493	349	269

Magnitude and frequency of annual high flow, based on period of record 1952-89

Magnitude and frequency of instantaneous peak flow, based on period of
record 1953-89

J		t per second, exceedance pr			
2	5	10	25	50	100
50%	20%	10%	4%	2%	1%

Period		_	nce interva	•	nd, for indicand exceedance	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%
1	3,050	5,400	7,440	10,700	13,600	17,000
3	2,990	5,320	7,370	10,600	13,600	17,100
7	2,830	5,060	7,070	10,400	13,400	17,100
15	2,660	4,710	6,600	9,740	12,700	16,400
30	2,370	4,050	5,590	8,160	10,600	13,600
60	2,100	3,240	4,200	5,690	7,020	8,570
90	1,950	2,810	3,480	4,460	5,280	6,190

Duration table of daily mean flow for period of record 1952-89

				Discha	arge, in cul	bic feet per	r second, v	which was	exceeded i	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
6,380	2,370	2,180	1,980	1,830	1,600	1,390	1,210	1,110	1,020	932	698	381	304	284	202	119

Site G54--South Fork Owl Creek near Anchor, Wyoming 06260000

Summary of monthly and annual discharge 1960-85 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1961-85

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent age of annual runoff
October	24	6.7	11	3.8	0.34	2.9
November	11	3.5	6.8	1.8	.27	1.7
December	8.0	1.2	4.6	1.8	.39	1.2
January	7.2	.08	3.4	2.1	.63	.9
February	6.2	.19	3.1	1.9	.60	.8
March	15	.32	5.1	3.2	.63	1.3
April	51	1.6	15	11	.69	3.8
May	142	25	73	30	.41	18.4
June	368	40	161	78	.49	40.5
July	203	16	74	52	.70	18.6
August	58	8.3	24	12	.50	6.1
September	36	6.7	16	6.8	.43	3.9
Annual	62	14	33	12	.36	100

Period		charge, in our rrence into pro	erval, in ye		onexceeda	
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100
1	0.00	0.00	0.03	0.13	0.33	1.2
3	.00	.00	.04	.17	.40	1.3
7	.00	.00	.05	.20	.48	1.6
14	1.9	.52	.21	.09	.03	.0
30	2.5	.76	.31	.13	.04	.0
60	2.7	1.1	.64	.38	.19	.1
90	3.1	1.5	1.0	.66	.40	.2
120	3.7	2.2	1.5	1.1	.71	.5
183	5.6	4.2	3.6	3.2	2.8	2.5

Magnitude and frequency of annual high flow, based on period of record 1960-85

Discharge		et per second, f exceedance pro			nterval, in
2 50%	5 20%	10 10%	25 4%	50 2%	100 1%
483	785	1,030	1,380	1,690	2,030

Period		currence i	cubic feet p nterval, in obability, in	years, and	exceedan	
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%
1	312	455	543	646	716	782
3	280	410	487	576	635	689
7	246	362	428	501	548	589
15	206	309	369	435	478	516
30	172	255	302	353	386	414
60	129	187	221	261	288	313
90	101	143	169	197	215	232

Duration table of daily mean flow for period of record 1960-85

				Disch	arge, in cu	bic feet pe	r second, v	which was	exceeded :	for indicat	ed percent	(%) of tim	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
321	166	94	61	41	22	14	9.9	7.1	5.5	4.1	2.3	1.1	0.47	0.27	0.11	0.02

Site G57--South Fork Owl Creek below Anchor Reservoir, Wyoming 06260400

Summary of monthly and annual discharge 1960-88 [ft³/s, cubic feet per second]

Magnitude and frequency of annual low flow, based on period of record 1961-88

Month	Maximum (ft ³ /s)	Minimum (ft ³ /s)	Mean (ft ³ /s)	Standard deviation (ft ³ /s)	Coeffi- cient of varia- tion	Percent- age of annual runoff
October	21	2.5	7.4	3.7	0.50	2.8
November	8.9	.01	2.7	2.1	.76	1.0
December	3.9	.00	.98	1.2	1.2	.4
January	2.4	.00	.40	.59	1.5	.2
February	2.8	.00	.71	.80	1.1	.3
March	8.7	.00	2.1	2.3	1.1	.8
April	30	1.0	10	7.7	.76	3.8
May	90	14	50	22	.45	18.9
June	226	35	98	45	.45	37.0
July	124	12	58	33	.57	21.9
August	60	4.2	23	15	.66	8.5
September	24	4.0	12	5.3	.45	4.5
Annual	36	11	22	6.7	.30	100

Period	recu		erval, in ye bability, ir			nce
(con- secutive days)	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%
1	0.00	0.00	0.00	0.00	0.00	0.00
3	.00	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00	.00
14	.00	.00	.00	.00	.00	.00
30	.00	.00	.00	.00	.00	.07
60	.00	.00	.00	.00	.00	.17
90	.00	.00	.00	.00	.03	.26
120	.00	.00	.00	.00	.12	.45
183	2.0	1.3	1.1	.96	.81	.73

Magnitude and frequency of annual high flow, based on period of record 1960-88

Ü		xceedance pr		l recurrence i percent (%)	nterval, i
			25	50	100
2	5	10			

Period		currence i	cubic feet protection of the contraction of the con	years, and	exceedan		
(con- secutive days)	2 50%	5 20%	10 10%	25 4%	50 2%	100 1%	
1	174	223	253	290	316	342	
3	166	213	241	272	294	314	
7	149	195	221	249	267	283	
15	131	175	199	223	238	251	
30	111	151	173	198	214	229	
60	87	117	134	154	167	180	
90	70	93	106	122	132	142	

Duration table of daily mean flow for period of record 1960-88

				Disch	arge, in cu	bic feet pe	r second, v	vhich was	exceeded	for indicat	ed percent	(%) of tin	ne			
1%	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%	95%	98%	99%	99.5%	99.9%
192	115	76	49	30	16	9.2	5.7	3.0	1.4	0.37	0.01	0.00	0.00	0.00	0.00	0.00

APPENDIX 2: STATISTICAL SUMMARIES OF WATER-QUALITY DATA FOR SELECTED STREAMFLOW-GAGING STATIONS ON OR NEAR THE WIND RIVER INDIAN RESERVATION, WYOMING, WITH 4 YEARS OR MORE OF MAJOR-CONSISTUENT ANALYSES THROUGH 1990

[Constituent, values in milligrams per liter except as indicated; %, percent; μS/cm, microsiemens per centimeter at 25 degrees Celsius; ^oC, degrees Celsius; JCU, Jackson candle units; μg/L micrograms per liter; pCi/L, picocuries per liter; CaCO₃, calcium carbonate; SiO₂, silica oxide; N, nitrogen; P, phosphorus; U-natural, uranium natural; Sr, strontium; Yt, yttrium; U, uranium; <, less than; --, no data. Statistical summaries are listed only when the sample size of the constituent is 11 or greater. Chemical-quality data less than the constituent detection limit are called censored data and were statistically analyzed using a log-probability regression procedure described in a report by Maddy and others (1990, p. 5-15 to 5-18)]

Site G2--Wind River above Red Creek, near Dubois, Wyoming 06220800 Range of sample dates: 1986-90

Sample size Maxi size size Maxi size size size size size size size siz		Descriptive statistics	stics		rei centage of samples in which values were less than or equal to those shown	or equal to those shown	own	
27 459 31 18 31 18 27 240 27 66 27 19 27 19 26 50 26 50 26 50 26 50 27 23 31 180 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 26 50 27 23			Minimum	95%	75%	(median) 50%	25%	2%
31 18 27 240 27 66 27 19 26 3 26 50 26 50 26 50 26 50 27 23 28 26 20 50 20 50 20 50 21 23 22 23 23 24 267			138	451	395	314	218	141
27 240 27 66 27 18 27 19 26 3 26 50 26 50 26 50 26 50 26 50 26 50 26 50 27 23 37 24			0.0	17	15	7.0	1.0	0.0
27 66 27 18 27 19 26 3 26 50 26 6 26 6 26 26 27 23 ants 24 267			49	228	190	150	93	53
27 18 27 19 26 3 24 180 26 50 26 50 26 50 27 23 nts 24 267			14	62	53	41	26	15
27 19 26 3 24 180 26 50 26 50 26 27 23 nts 24 267			3.4	17	14	12	8.9	3.5
26 3 24 180 26 50 26 6 26 6 27 23 nts 24 267			4.0	17	12	11	7.1	4.1
24 180 26 50 26 6 26 6 27 23 nts 24 267			1.0	3.7	2.9	2.6	1.7	1.1
26 50 26 6 26 2 27 23 nts 24 267			52	180	150	125	88	54
26 6 26 23 27 23 outs 24 267			7.1	48	37	33	20	7.5
26 27 23 nts 24 267			.30	6.4	4.7	3.8	2.5	.54
27 2 nts 24 26			.10	.56	.40	.30	.20	.10
nts 24 26			7.3	23	21	19	17	9.6
90			70	366	236	200	130	74
ì	Nitrite plus nitrate, dissolved as N	5 1.3	<.10	1.2*	.20*	.10*	*20.	*00.
Phosphorus, total as P 26 1.1			<.03	* <i>LL</i> :	*90.	.04*	.03*	*10.
Selenium (µg/L) 18 <5.0			<1.0	;	;	:	1	1

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G16--Wind River near Crowheart, Wyoming 06225500 Range of sample dates: 1970-90

		Descriptive statistics	iics	Percer	ntage of sample or equ	Percentage of samples in which values were less than or equal to those shown	ues were less own	than
Constituent	Sample size	Maximum	Minimum	95%	75%	(median) 50%	25%	2%
Specific conductance (µS/cm)	29	570	100	503	358	253	140	110
Water temperature (°C)	237	22	0.0	18	15	11	5.0	0.0
Hardness, total as CaCO ₃	23	210	49	208	170	130	<i>L</i> 9	50
Calcium, dissolved	23	57	13	57	46	33	19	13
Magnesium, dissolved	23	17	3.1	17	14	10	4.8	3.2
Sodium, dissolved	23	47	4.5	41	16	12	6.3	4.5
Potassium, dissolved	22	3.3	.80	3.2	2.7	2.2	1.1	.80
Alkalinity, total as CaCO ₃	19	190	41	190	150	86	58	41
Sulfate, dissolved	21	66	8.2	16	50	35	17	8.9
Chloride, dissolved	22	0.9	<1.0	*0.9	3.3*	2.8*	1.6*	*06
Fluoride, dissolved	22	.70	.10	.70	.30	.30	.18	.10
Silica, dissolved as SiO ₂	23	20	3.9	20	16	15	12	4.4
Dissolved solids, sum of constituents	19	350	<i>L</i> 9	350	231	154	101	<i>L</i> 9
Nitrite plus nitrate, dissolved as N	22	.50	<.10	*47*	.20*	.10*	*50.	*20.
Phosphorus, total as P	22	.28	<.03	.26*	*50.	.03*	*00.	.01*
Selenium, dissolved (µg/L)	16	<5.0	<1.0	ŀ	ŀ	ł	I	;

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G22--Wind River at Riverton, Wyoming 06228000 Range of sample dates: 1947-90

	Ğ	Descriptive statistics	lics	Percen	Percentage of samples in which values were less than or equal to those shown	samples in which values or equal to those shown	ues were less	than
	Sample	•				(median)		
Constituent	size	Maximum	Minimum	%56	75%	20%	25%	2%
Specific conductance (µS/cm)	305	740	144	999	474	414	296	198
pH (units)	293	8.9	7.0	8.5	8.2	8.0	7.8	7.3
Water temperature (°C)	410	28.5	0.	22	17	13	5.4	0.
Turbidity (JCU)	58	06	1.0	80	20	5.5	3.0	1.0
Hardness, total as CaCO ₃	358	270	09	220	190	160	110	79
Calcium, dissolved	358	71	18	62	51	44	32	23
Magnesium, dissolved	358	23	.80	61	14	12	7.7	4.4
Sodium, dissolved	330	96	4.9	48	32	26	20	8.9
Potassium, dissolved	333	5.2	0.	3.4	2.8	2.4	2.0	1.2
Alkalinity, total as CaCO ₃	358	240	09	194	160	135	100	70
Sulfate, dissolved	358	200	6.6	120	85	69	49	21
Chloride, dissolved	358	23	.10	11	7.0	5.2	3.5	1.5
Fluoride, dissolved	357	1.6	0.	.50	.40	.30	.20	.10
Silica, dissolved as SiO ₂	358	29	.10	20	17	14	12	8.2
Dissolved solids, sum of constituents	330	548	68	369	303	263	191	121
Nitrate, dissolved as N	98	1.3	0.	.37	.18	.07	.02	0.
Nitrite plus nitrate, dissolved as N	09	1.9	<.10	.40*	.21*	.10*	*40.	.03*
Phosphorus, total as P	130	09:	<.01	.26*	*50.	.03*	.01*	.004*
Arsenic, dissolved (μg/L)	17	3.0	<1.0	3.0*	2.0*	1.0*	1.0*	.47*
Barium, dissolved (μg/L)	16	75	40	75	70	09	51	40
Boron, dissolved (µg/L)	197	009	0.	191	70	50	30	10
Chromium, dissolved	16	3.0	<1.0	3.0*	2.0*	*:	.78*	*44*
Iron, dissolved (μg/L)	41	130	<3.0	113*	30*	19*	8.1*	2.8*
Manganese, dissolved (µg/L)	16	16	2	16	8.6	8.0	5.0	2.0
Mercury, dissolved (µg/L)	14	.40	<.10	.40*	.22*	.13*	*80.	*50.
Selenium (µg/L)	15	<3.0	<1.0	!	1	;	1	1
Alpha, gross, dissolved as U-natural (μg/L)	19	24	<3.0	24*	6.4*	5.4*	3.3*	2.2*
Beta, gross, dissolved as Sr/Yt-90 (pCi/L)	19	10	1.0	10	5.7	4.5	3.4	1.0
Radium 226, dissolved, radon method (pCi/L)	19	1.0	<.20	1.0*	.22*	.12*	.10*	*60
Uranium, natural (µg/L)	19	22	1.8	22	6.2	4.2	3.2	1.8

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G23--South Fork Little Wind River above Washakie Reservoir, near Fort Washakie, Wyoming 06228350 Range of sample dates: 1976-90

	De	Descriptive statistics	ics	Percen	tage of sample or equ	Percentage of samples in which values were less than or equal to those shown	ues were less t	han
	Sample					(median)		
Constituent	size	Maximum	Minimum	%56	%5 2	20%	72%	2%
Specific conductance (µS/cm)	116	200	24	146	26	49	49	29
pH (units)	30	8.4	6.7	8.3	7.7	7.4	7.2	6.7
Water temperature (°C)	118	19	0.	16	10	5.0	1.0	0.
Hardness, total as CaCO ₃	116	98	0.6	09	46	28	17	12
Calcium, dissolved	116	21	2.3	15	12	7.7	4.7	3.3
Magnesium, dissolved	116	8.2	.30	5.3	3.8	2.3	1.3	.70
Sodium, dissolved	116	9.3	.90	6.1	4.4	2.8	1.8	66.
Potassium, dissolved	115	2.0	0.	1.1	.80	09.	.50	.30
Alkalinity, total as CaCO ₃	114	69	0.9	47	36	22	15	10
Sulfate, dissolved	114	13	0.	10	6.3	4.6	2.8	1.2
Chloride, dissolved	114	25	.40	11	8.3	4.4	1.8	.80
Fluoride, dissolved	114	.70	<.10	.20*	.10*	.10*	*90`	.04*
Silica, dissolved as SiO ₂	116	27	1.2	7.9	9.9	4.7	3.0	2.1
Dissolved solids, sum of constituents	110	123	15	82	63	42	26	19
Nitrite plus nitrate, dissolved as N	108	1.6	<.10	.22*	.12*	*80	.04*	.01*
Phosphorus, total as P	112	2.2	<.01	*50.	.02*	.01*	*400.	*100.
Selenium (µg/L)	14	<5.0	<1.0	;	:	:	;	-

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G34--Ray Lake outlet near Fort Washakie, Wyoming 06230300 Range of sample dates: 1960-70

	De	Descriptive statistics	tics	Percei	ntage of samp or eq	Percentage of samples in which values were less than or equal to those shown	lues were less own	than
Constituent	Sample size	Maximum	Minimum	%96	75%	(median) 50%	25%	2%
Specific conductance (µS/cm)	37	766	879	975	892	788	716	682
pH (units)	37	8.0	6.9	8.0	7.6	7.4	7.2	6.9
Hardness, total as CaCO3	37	310	190	310	270	230	210	190
Calcium, dissolved	37	69	33	89	55	44	35	33
Magnesium, dissolved	37	37	24	36	32	30	26	24
Sodium, dissolved	37	110	25	101	91	79	70	64
Potassium, dissolved	37	3.6	.30	3.1	2.7	2.1	1.4	.39
Alkalinity, total as CaCO ₃	37	137	62	136	118	86	77	65
Sulfate, dissolved	37	370	220	361	330	300	255	229
Chloride, dissolved	37	11	6.2	6.7	8.6	8.1	7.2	6.4
Fluoride, dissolved	37	.40	.10	.40	.30	.20	.20	.19
Silica, dissolved as SiO ₂	37	8.1	.40	5.8	5.0	3.3	2.3	1.4
Dissolved solids, sum of constituents	37	999	432	662	929	503	459	432
Nitrate, dissolved as N	32	.32	0.	.29	.20	60.	.05	0.
Boron, dissolved (µg/L)	37	130	50	121	06	80	70	09

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G36--Little Wind River above Arapahoe, Wyoming 06231000 Range of sample dates: 1966-90

	۵	Descriptive statistics	ics	Percer	ntage of sample or equ	samples in which val or equal to those sh	Percentage of samples in which values were less than or equal to those shown	than
ı	Sample					(median)		
Constituent	size	Maximum	Minimum	%56	75%	20%	25%	2%
Specific conductance (µS/cm)	171	2,160	179	1,428	1,080	006	709	310
pH (units)	140	8.7	7.0	8.5	8.3	8.0	7.8	7.4
Water temperature (°C)	241	25	0.	22	16	10	0.	0.
Turbidity (JCU)	48	55	1.0	33	14	5.0	2.0	1.0
Hardness, total as CaCO ₃	226	800	<i>L</i> 9	516	410	350	288	110
Calcium, dissolved	226	140	18	100	06	79	64	28
Magnesium, dissolved	226	110	5.4	64	46	37	29	9.4
Sodium, dissolved	226	260	8.0	137	88	89	47	16
Potassium, dissolved	228	6.5	.10	4.4	3.2	2.6	2.0	1.2
Alkalinity, total as CaCO ₃	224	240	48	210	180	160	140	92
Sulfate, dissolved	224	1,000	31	580	400	310	230	11
Chloride, dissolved	226	33	.10	21	14	10	8.5	2.2
Fluoride, dissolved	226	0.9	0.	06:	.70	.50	.40	.20
Silica, dissolved as SiO ₂	224	16	0.	12	9.2	7.1	5.6	3.4
Dissolved solids, sum of constituents	222	1,650	102	1,020	755	615	476	184
Nitrate, dissolved as N	79	.61	0.	.45	.34	.16	.07	0.
Nitrite plus nitrate, dissolved as N	73	.70	<.10	*44*	.30*	.10*	*90`	.03*
Phosphorus, total as P	149	.84	<.01	.15*	*50.	.02*	*10	.004
Boron, dissolved (µg/L)	68	250	0.	215	150	100	80	30
Iron, dissolved (µg/L)	33	180	<10	166*	55*	30*	*02	*9.9
Selenium (µg/L)	14	<5.0	<1.0	1	1	1	;	;
Alpha, gross, dissolved as U-natural (μg/L)	20	17	<1.0	17*	11*	7.9*	3.6*	2.3*
Beta, gross, dissolved as Sr/Yt-90 (pCi/L)	20	17	<3.9	17*	*8.9	5.4*	3.7*	2.8*
Radium 226, dissolved, radon method (pCi/L)	20	06'	<.20	*06	.65*	.40*	.30*	.16*
Uranium, natural (µg/L)	20	12	1.8	12	8.2	6.4	3.7	1.8

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G42--Popo Agie River near Arapahoe, Wyoming 06233900 Range of sample dates: 1980-90

	De	Descriptive statistics	ics	Percer	itage of sample or equ	samples in which values or equal to those shown	Percentage of samples in which values were less than or equal to those shown	than
Constituent	Sample	Maximum	Minimum	%56	75%	(median) 50%	25%	2%
Specific conductance (µS/cm)	114	1,450	188	1,040	968	816	605	287
Water temperature (°C)	119	24.5	0.	22	18	12	5.0	0.
Hardness, total as CaCO ₃	117	520	72	413	375	340	250	109
Calcium, dissolved	117	120	19	100	87	08	61	28
Magnesium, dissolved	1117	59	0.9	46	38	32	23	9.1
Sodium, dissolved	117	120	7.4	81	62	50	35	13
Potassium, dissolved	116	7.3	09:	3.8	2.7	2.4	1.9	1.1
Alkalinity, total as CaCO ₃	114	250	51	213	180	160	130	99
Sulfate, dissolved	116	570	35	380	310	250	180	99
Chloride, dissolved	115	11	90.	8.7	6.3	5.0	3.6	1.4
Fluoride, dissolved	116	09:	.10	.40	.30	.30	.20	.10
Silica, dissolved as SiO_2	117	13	1.9	12	9.2	8.2	6.7	5.1
Dissolved solids, sum of constituents	113	1,020	118	741	622	541	389	163
Nitrite plus nitrate, dissolved as N	96	1.6	<.10	1.2*	.32*	.10*	*00.	*10.
Phosphorus, total as P	06	.72	.01	.39	80.	90.	.04	.02
Selenium (µg/L)	21	<5.0	<1.0	ł	ł	1	1	i
Alpha, gross, dissolved as U-natural (μg/L)	17	11	<3.0	11*	*9'6	5.3*	3.0*	1.7*
Beta, gross, dissolved as Sr/Yt-90 (pCi/L)	17	18	<4.7	18*	5.7*	4.3*	3.1*	.50*
Radium 226, dissolved, radon method (pCi/L)	17	.40	<.20	*40*	.15*	.12*	*11.	*80
Uranium, natural (µg/L)	17	8.6	1.5	8.6	8.9	5.7	4.3	1.5

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G44--Beaver Creek near Arapahoe, Wyoming 06235000 Range of sample dates: 1951-90

	ă	Descriptive statistics	tics	Percel	ntage of sampl or equ	samples in which values or equal to those shown	Percentage of samples in which values were less than or equal to those shown	than
Ĭ	Sample					(median)		
Constituent	size	Maximum	Minimum	% 26	75%	20%	25%	2%
Specific conductance (µS/cm)	11	3,060	552	2,720	2,090	1,790	1,070	613
pH (units)	98	9.8	7.2	8.4	8.2	8.0	7.8	7.4
Water temperature (°C)	126	32	0.	27	14	0.9	0.	0.
Hardness, total as CaCO ₃	112	086	130	887	089	260	360	193
Calcium, dissolved	112	280	35	250	190	150	100	57
Magnesium, dissolved	112	96	8.9	<i>L</i> 9	50	39	24	12
Sodium, dissolved	110	390	35	310	230	180	100	46
Potassium, dissolved	114	93	1.1	15	10	7.9	6.3	3.7
Alkalinity, total as CaCO ₃	112	430	82	300	240	200	160	110
Sulfate, dissolved	112	1,100	110	1,000	725	009	350	146
Chloride, dissolved	112	230	17	180	138	100	52	23
Fluoride, dissolved	112	3.5	.30	1.8	1.2	1.0	.70	.40
Silica, dissolved as SiO ₂	112	28	0.	22	19	17	15	10
Dissolved solids, sum of constituents	110	2,270	307	2,000	1,500	1,260	962	375
Nitrate, dissolved as N	57	.70	0.	.39	.17	60.	.04	0.
Nitrite plus nitrate, dissolved as N	15	1.0	0.	1.0	.30	.19	.11	0.
Phosphorus, total as P	62	2.0	<.01	*65	.26*	*90.	*00.	.003*
Boron, dissolved (µg/L)	50	610	30	504	378	265	140	65
Iron, dissolved (µg/L)	17	260	<10	260*	*59	*0*	16*	4.7*
Alpha, gross, dissolved as U-natural (μg/L)	15	09	<3.0	*09	16*	*9.6	7.8*	3.6*
Beta, gross, dissolved as Sr/Yt-90 (pCi/L)	15	83	<18	83*	23*	14*	8.6*	1.5*
Radium 226, dissolved, radon method (pCi/L)	15	1.6	<.10	1.6*	.38*	.18*	.14*	.03*
Uranium, natural (µg/L)	15	19	4.0	19	12	11	7.7	4.0

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G45--Little Wind River near Riverton, Wyoming 06235500 Range of sample dates: 1953-90

	۵	Descriptive statistics	tics	Percer	itage of sample or equ	Percentage of samples in which values were less than or equal to those shown	lues were less own	than
ı	Sample					(median)		
Constituent	size	Maximum	Minimum	92%	75%	20%	25%	2%
Specific conductance (µS/cm)	250	1,590	204	1,230	086	852	647	279
pH (units)	247	8.6	6.9	8.5	8.2	8.0	7.8	7.3
Water temperature (°C)	348	26	0.	22	17	12	4.0	0.
Hardness, total as CaCO ₃	303	540	99	450	380	330	260	110
Calcium, dissolved	301	120	14	100	96	62	09	28
Magnesium, dissolved	301	85	3.0	49	39	33	24	7.1
Sodium, dissolved	296	160	0.6	110	75	61	46	12
Potassium, dissolved	298	49	.10	4.6	3.1	2.6	2.0	1.2
Alkalinity, total as CaCO ₃	303	246	45	200	180	160	130	<i>L</i> 9
Sulfate, dissolved	303	640	38	470	340	290	210	99
Chloride, dissolved	303	30	.10	. 20	13	9.6	7.1	2.5
Fluoride, dissolved	302	5.0	0.	.70	09:	.50	.40	.20
Silica, dissolved as SiO ₂	303	32	.20	14	10	8.3	6.5	4.7
Dissolved solids, sum of constituents	297	1,130	111	898	674	578	451	167
Nitrate, dissolved as N	84	1.3	0.	.73	.40	.14	.05	0.
Nitrite plus nitrate, dissolved as N	41	1.0	0.	.73	.30	.10	.02	0.
Phosphorus, total as P	1117	1.6	<.01	.52*	.11*	.04	*00.	.004*
Boron, dissolved (µg/L)	190	920	0.	180	120	06	09	16
Iron, dissolved (µg/L)	23	200	<10	188	50	20	8.5	2.5
Alpha, gross, dissolved as U-natural (µg/L)	20	16	\wp	16*	13*	6.4*	3.6*	2.7*
Beta, gross, dissolved as Sr/Yt-90 (pCi/L)	20	15	<6.5	15*	7.0*	5.1*	4.6*	2.4*
Radium 226, dissolved, radon method (pCi/L)	20	09'	<.02	.59*	.24*	.18*	.15*	.03*
Uranium, natural (µg/L)	20	6.7	1.3	9.6	7.9	6.3	4.9	1.3

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G48--Wind River above Boysen Reservoir, near Shoshoni, Wyoming 06236100 Range of sample dates: 1973-90

	Ďě	Descriptive statistics	tics	Percent	age of sample: equa	nples in which values equal to those shown	Percentage of samples in which values were less than or equal to those shown	an or
tour History	Sample	Movimum	Minim	70	76%	(median)	25%	76
	2710			8/00	20	2/20	20/02	8
Specific conductance (µS/cm)	92	1,100	193	843	704	009	520	262
pH (units)	26	9.8	7.2	8.6	8.2	8.0	7.9	7.5
Water temperature (°C)	191	25	0.	21	17	0.6	0.	0:
Turbidity (JCU)	9/	1,300	1.0	266	50	10	4.0	1.0
Hardness, total as CaCO ₃	102	400	74	328	272	250	198	80
Calcium, dissolved	102	96	20	81	71	64	49	22
Magnesium, dissolved	102	39	5.5	31	25	22	18	6.2
Sodium, dissolved	102	110	9.2	80	55	46	37	12
Potassium, dissolved	102	4.9	.80	3.9	3.1	2.8	2.4	1.5
Alkalinity, total as CaCO ₃	78	270	53	210	190	170	140	65
Sulfate, dissolved	102	400	29	270	180	160	130	44
Chloride, dissolved	102	34	06:	15	9.8	8.9	5.1	2.0
Fluoride, dissolved	102	09.	.10	.50	.40	.40	.30	.12
Silica, dissolved as SiO ₂	101	23	6.3	17	13	11	9.4	7.3
Dissolved solids, sum of constituents	102	775	115	617	467	422	336	134
Nitrite plus nitrate, dissolved as N	95	.71	<.10	*64:	.30*	.11*	.04*	.01*
Phosphorus, total as P	110	.65	<.01	.39*	.13*	*40.	.04*	*00.
Boron, dissolved (µg/L)	25	120	30	114	85	70	70	33

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G50--Fivemile Creek above Wyoming Canal, near Pavillion, Wyoming 06244500 Range of sample dates: 1949-90

	Ď	Descriptive statistics	tics	Perce	ntage of sampl or eq	Percentage of samples in which values were less than or equal to those shown	lues were less own	than
Constituent	Sample	Maximum	Minimum	95%	75%	(median) 50%	25%	5%
Specific conductance (µS/cm)	63	5,750	2,370	5,270	4,760	4,000	3,380	2,820
pH (units)	37	8.4	7.1	8.4	7.9	7.7	7.6	7.3
Water temperature (°C)	88	28	0.	27	15	10	4.0	0.
Turbidity (JCU)	18	200	0.	200	15	2.5	1.0	0.
Hardness, total as CaCO ₃	51	2,100	1,000	2,000	1,900	1,800	1,600	1,360
Calcium, dissolved	51	069	310	580	490	460	430	362
Magnesium, dissolved	51	240	18	210	170	140	120	57
Sodium, dissolved	29	820	220	798	290	360	290	238
Potassium, dissolved	48	21	.50	17	12	11	8.6	8.6
Alkalinity, total as CaCO ₃	69	240	68	230	200	170	160	130
Sulfate, dissolved	70	3,500	1,300	3,200	2,800	2,400	2,050	1,560
Chloride, dissolved	70	92	18	83	70	65	59	38
Fluoride, dissolved	50	1.8	09.	1.4	1.2	1.2	1.1	.70
Silica, dissolved as SiO ₂	50	22	4.8	15	11	8.9	7.9	5.3
Dissolved solids, sum of constituents	47	5,080	2,320	4,830	3,850	3,360	2,930	2,470
Nitrate, dissolved as N	28	.18	0.	.17	90.	.02	.02	0.
Nitrite plus nitrate, dissolved as N	19	.30	<.01	.30*	.10*	*90`	.03*	*10.
Phosphorus, total as P	46	.17	<.01	.11*	*00.	*900	*005	*000
Selenium, dissolved (µg/L)	15	4.0	<1.0	1	-	-	*	:

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.

Site G53--Wind River below Boysen Reservoir, Wyoming 06259000 Range of sample dates: 1953-90

	č	Descriptive etatistics	90	Percer	itage of sample	Percentage of samples in which values were less than	values were less	than
1	5	southine statis	2		מאלי	ימו נס נווספב פווי		
Constituent	Sample size	Maximum	Minimum	95%	75%	(median) 50%	25%	2%
Specific conductance (µS/cm)	462	1,460	322	1,050	794	269	614	483
pH (units)	399	8.8	6.3	8.4	8.2	7.9	7.6	7.1
Water temperature (°C)	224	24	0.	20	16	10	4.0	2.0
Turbidity (JCU)	79	100	1.0	10	4.0	2.0	1.0	1.0
Hardness, total as CaCO ₃	469	480	120	315	240	210	190	150
Calcium, dissolved	455	120	30	81	62	57	50	40
Magnesium, dissolved	455	47	7.3	27	21	18	15	11
Sodium, dissolved	468	160	32	100	77	65	56	40
Potassium, dissolved	439	5.0	.10	3.8	2.9	2.6	2.3	2.0
Alkalinity, total as CaCO ₃	452	210	82	180	150	140	120	100
Sulfate, dissolved	450	260	94	354	240	200	170	130
Chloride, dissolved	441	99	.10	15	9.6	8.1	9.9	4.8
Fluoride, dissolved	440	4.0	0.	09.	.40	.40	.30	.20
Silica, dissolved as SiO ₂	455	17	3.7	12	8.6	8.8	7.8	6.1
Dissolved solids, sum of constituents	437	1,050	246	692	909	443	386	300
Nitrate, dissolved as N	87	.54	0.	.35	.18	.14	60.	0.
Nitrite plus nitrate, dissolved as N	83	2.3	<.10	*65.	.20*	.14*	*40.	.03*
Phosphorus, total as P	151	.27	<.01	*80	.04*	*00.	.01*	*900
Arsenic, dissolved (μg/L)	46	4.0	1.0	3.6	3.0	2.0	2.0	1.0
Barium, dissolved (µg/L)	45	200	<100	100*	*69	63*	*65	54*
Boron, dissolved (µg/L)	271	270	10	140	100	70	09	40
Cadmium	49	3.0	<1.0	2.5*	.64*	.31*	.14*	*50.
Chromium, dissolved (µg/L)	49	20	<1.0	15*	1.7*	.40*	.12*	.03*
Iron, dissolved (µg/L)	75	290	<10	*902	*02	*02	8.7*	4.2*
Manganese, dissolved (µg/L)	46	240	<1.0	145*	15*	*0.9	2.9*	.75*
Mercury, dissolved (µg/L)	46	0.6	<.10	4.4*	.10*	.01*	.001*	*000
Selenium, dissolved (µg/L)	48	2.0	<1.0	1.6*	1.0*	1.0*	*08	*40.
Alpha, gross, dissolved as U-natural (μg/L)	13	19	<7.8	.19*	15*	12*	9.4*	8.1*
Beta, gross, dissolved as Sr/Yt-90 (pCi/L)	13	8.0	<3.4	*0.8	6.4*	5.5*	*8.4	3.9*
Radium 226, dissolved, radon method (pCi/L)	13	.19	.07	.19	.15	.11	.10	.07
Uranium, natural (µg/L)	13	11	5.2	11	10	9.3	7.9	5.2

*Value is estimated by using a log-probability regression to predict the values of data less than the detection limit.